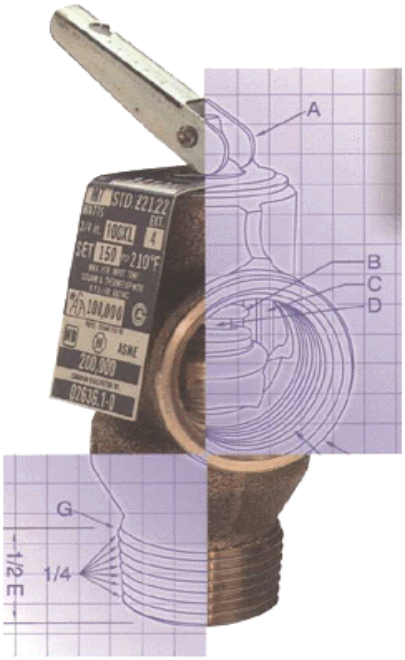
Section II A - Ferrous Material Specifications

- Foreword
- Statements of Policy
- Guideline
- Personnel
- ASTM Personnel
- Preface
- Specification Listed by Materials
- Specification Listed in Numeric Sequence
- Appendix 1 - Mandatory Preparation of Technical Inquiries to the Boiler and Pressure Vessel Committee
- Appendix A - Nonmandatory Acceptable ASTM Edition
- Appendix B - Nonmadatory Guidelines on Multiple Marking of Materials
- SI Units
- Summary of Changes
- SA-6
- SA-20
- SA-29
- SA-36
- SA-47
- SA-53
- SA-105
- SA-106
- SA-134
- SA-135
- SA-178
- SA-179
- SA-181
- SA-182
- SA-192
- SA-193
- SA-194
- SA-199
- SA-202
- SA-203
- SA-312
- SA-320
- SA-325
- SA-333
- SA-334
- SA-335
- SA-336
- SA-350
- SA-351
- SA-352
- SA-353
- SA-354
- SA-358
- SA-369
- SA-370
- SA-372
- SA-376
- SA-387
- SA-388
- SA-395
- SA-403
- SA-409
- SA-414
- SA-420
- SA-423
- SA-426
- SA-430
- SA-435
- SA-437
- SA-449
- SA-450
- SA-451
- SA-452
- SA-453
- SA-455
- SA-476
- SA-479



- SA-612
- SA-620
- SA-638
- SA-645
- SA-649
- SA-660
- SA-662
- SA-666
- SA-667
- SA-671
- SA-672
- SA-675
- SA-688
- SA-691
- SA-693
- SA-695
- SA-696
- SA-703
- SA-705
- SA-723
- SA-724

- SA-204
- SA-209
- SA-210
- SA-213
- SA-214
- SA-216
- SA-217
- SA-225
- SA-226
- SA-232
- SA-234
- SA-240
- SA-249
- SA-250
- SA-263
- SA-264
- SA-265
- SA-266
- SA-268
- SA-275
- SA-278
- SA-283
- SA-285
- SA-299
- SA-302
- SA-307
- SA-311
- SA-480
- SA-484
- SA-487
- SA-494
- SA-508
- SA-515
- SA-516
- SA-517
- SA-522
- SA-524
- SA-530
- SA-533
- SA-540
- SA-541
- SA-542
- SA-543
- SA-553
- SA-556
- SA-557
- SA-562
- SA-563
- SA-564
- SA-574
- SA-577
- SA-578
- SA-587
- SA-592
- SA-609
- SA-727
- SA-731
- SA-736
- SA-737
- SA-738
- SA-739
- SA-745
- SA-747
- SA-748
- SA-751
- SA-765
- SA-770
- SA-781
- SA-788
- SA-789
- SA-790
- SA-803
- SA-812
- SA-813
- SA-814
- SA-815
- SA-832
- SA-834
- SA-836
- SA-841
- SA-905
- SA/CSA-G40.21
- SA/EN 10028-2
- SA/JIS G3118
- Interpretations

IMPORTANT INFORMATION ON THE 1998 BOILER AND PRESSURE VESSEL CODE ADDENDA DISTRIBUTION SCHEDULE

There is a change in the way the Addenda to the 1998 Edition of the ASME Boiler and Pressure Vessel Code are distributed. The 1998 Edition, published July 1, 1998, incorporates the 1998 Addenda revisions, additions, or deletions. There will be no separate 1998 Addenda issued in a replacement page format. Two additional Addenda to the 1998 Edition, in the form of replacement pages, will be issued on July 1, 1999 and July 1, 2000.

The Summary of Changes published with the 1998 Edition lists and describes the revisions that are part of the 1998 Addenda. These changes are identified with a margin note, **98**, denoting the affected area.

The Addenda for 1999 and 2000 will also have a Summary of Changes and identifiers printed on the replacement pages. The revisions, additions, or deletions will be incorporated directly into the affected pages. It is advisable to retain the title sheets and all replaced pages for reference.

The effective dates for Code Editions and Addenda are described in the Foreword.

No part of this document may be reproduced in any form,
in an electronic retrieval system or otherwise,
without the prior written permission of the publisher.

The American Society of Mechanical Engineers
Three Park Avenue, New York, NY 10016-5990

Copyright © 1999 by
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
All Rights Reserved
Printed in U.S.A.

ASME BOILER AND PRESSURE VESSEL CODE

AN INTERNATIONAL CODE

MATERIALS

II

Part A –

Ferrous Material Specifications

1999 Addenda
July 1, 1999

ASME BOILER AND PRESSURE VESSEL COMMITTEE SUBCOMMITTEE ON MATERIALS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

NEW YORK, NEW YORK

Q02AW9

Date of Issue — July 1, 1998
(Includes all Addenda dated December 1997 and earlier)

This code or standard was developed under procedures accredited as meeting the criteria for American National Standards. The Consensus Committee that approved the code or standard was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed code or standard was made available for public review and comment which provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

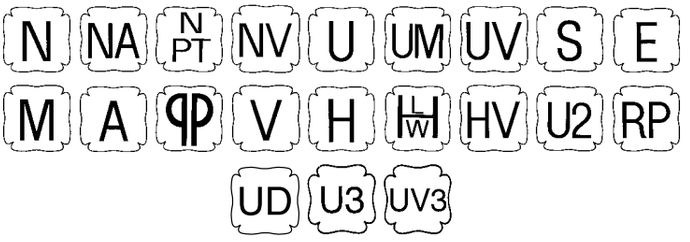
ASME does not "approve," "rate," or "endorse" any item, construction, proprietary device, or activity.

ASME does not take any position with respect to the validity of any patent rights asserted in connection with any items mentioned in this document, and does not undertake to insure anyone utilizing a standard against liability for infringement of any applicable Letters Patent, nor assume any such liability. Users of a code or standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

Participation by federal agency representative(s) or person(s) affiliated with industry is not to be interpreted as government or industry endorsement of this code or standard.

ASME accepts responsibility for only those interpretations issued in accordance with governing ASME procedures and policies which preclude the issuance of interpretations by individual volunteers.

ASME collective membership mark



The above ASME symbols are registered in the U.S. Patent Office.
"ASME" is the trademark of the American Society of Mechanical Engineers.

The Specifications published and copyrighted by The American Society for Testing and Materials are reproduced with the Society's permission.

No part of this document may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

Library of Congress Catalog Card Number: 56-3934
Printed in the United States of America

Adopted by the Council of the American Society of Mechanical Engineers, 1914.
Revised 1940, 1941, 1943, 1946, 1949, 1952, 1953, 1956, 1959, 1962, 1965, 1968, 1971, 1974, 1977, 1980, 1983, 1986, 1989, 1992, 1995, 1998

The American Society of Mechanical Engineers
Three Park Avenue, New York, NY 10016-5990

Copyright © 1998 by
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
All Rights Reserved

1998 ASME
BOILER AND PRESSURE VESSEL CODE

A99 **SECTIONS**

I Rules for Construction of Power Boilers
II Materials
- Part A — Ferrous Material Specifications
- Part B — Nonferrous Material Specifications
- Part C — Specifications for Welding Rods, Electrodes, and Filler Metals
- Part D — Properties

III Subsection NCA — General Requirements for Division 1 and Division 2
III Division 1
- Subsection NB — Class 1 Components
- Subsection NC — Class 2 Components
- Subsection ND — Class 3 Components
- Subsection NE — Class MC Components
- Subsection NF — Supports
- Subsection NG — Core Support Structures
- Subsection NH — Class 1 Components in Elevated Temperature Service
- Appendices

III Division 2 — Code for Concrete Reactor Vessels and Containments
III Division 3 — Containment Systems for Storage and Transport Packagings of Spent Nuclear Fuel and High Level Radioactive Material and Waste
IV Rules for Construction of Heating Boilers
V Nondestructive Examination
VI Recommended Rules for the Care and Operation of Heating Boilers
VII Recommended Guidelines for the Care of Power Boilers
VIII Rules for Construction of Pressure Vessels
- Division 1
- Division 2 — Alternative Rules
- Division 3 — Alternative Rules for Construction of High Pressure Vessels

IX Welding and Brazing Qualifications
X Fiber-Reinforced Plastic Pressure Vessels
XI Rules for Inservice Inspection of Nuclear Power Plant Components

ADDENDA

Colored-sheet Addenda, which include additions and revisions to individual Sections of the Code, are published annually and will be sent automatically to purchasers of the applicable Sections up to the publication of the 2001 Code. The 1998 Code is available only in the loose-leaf format; accordingly, the Addenda will be issued in the loose-leaf, replacement-page format.

INTERPRETATIONS

ASME issues written replies to inquiries concerning interpretation of technical aspects of the Code. The Interpretations for each individual Section will be published separately and will be included as part of the update service to that Section. They will be issued semiannually (July and December) up to the publication of the 2001 Code. Interpretations of Section III, Divisions 1 and 2, will be included with the update service to Subsection NCA.

CODE CASES

The Boiler and Pressure Vessel Committee meets regularly to consider proposed additions and revisions to the Code and to formulate Cases to clarify the intent of existing requirements or provide, when the need is urgent, rules for materials or constructions not covered by existing Code rules. Those Cases which have been adopted will appear in the appropriate 1998 Code Cases book: (1) Boilers and Pressure Vessels and (2) Nuclear Components. Supplements will be sent automatically to the purchasers of the Code Cases books up to the publication of the 2001 Code.

CONTENTS

Foreword vii
Statements of Policy xi
Guideline xiii
Personnel xv
ASTM Personnel xxv
Preface xxvii
Specification Listed by Materials xxix
Specification Listed in Numeric Sequence xxxv
Appendix 1 — Mandatory Preparation of Technical Inquiries to the Boiler and Pressure Vessel Committee xxxix
Appendix A — Nonmandatory Acceptable ASTM Edition xli
Appendix B — Nonmandatory Guidelines on Multiple Marking of Materials li
SI Units liii
Summary of Changes lvii

FOREWORD

The American Society of Mechanical Engineers set up a committee in 1911 for the purpose of formulating standard rules for the construction of steam boilers and other pressure vessels. This committee is now called the Boiler and Pressure Vessel Committee.

The Committee's function is to establish rules of safety governing the design, fabrication, and inspection during construction of boilers and pressure vessels, and to interpret these rules when questions arise regarding their intent. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of pressure vessels. The objective of the rules is to afford reasonably certain protection of life and property and to provide a margin for deterioration in service so as to give a reasonably long, safe period of usefulness. Advancements in design and material and the evidence of experience have been recognized.

This Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction[1] activities. The Code does not address all aspects of these activities and those aspects which are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase *engineering judgment* refers to technical judgments made by knowledgeable designers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code neither requires nor prohibits the use of computers for the design or analysis of components constructed to the requirements of the Code. However, designers and engineers using computer programs for design or analysis are cautioned that they are responsible for all technical assumptions inherent in the programs they use and they are responsible for the application of these programs to their design.

The Code does not fully address tolerances. When dimensions, sizes, or other parameters are not specified with tolerances, the values of these parameters are considered nominal and allowable tolerances or local variances may be considered acceptable when based on engineering judgment and standard practices as determined by the designer.

The Boiler and Pressure Vessel Committee deals with the care and inspection of boilers and pressure vessels in service only to the extent of providing suggested rules of good practice as an aid to owners and their inspectors.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Boiler and Pressure Vessel Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code Cases, and requests for interpretations. Only the Boiler and Pressure Vessel Committee has the authority to provide official interpretations of this Code. Requests for revisions, new rules, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action (see Mandatory Appendix covering preparation of technical inquiries). Proposed revisions to the Code resulting from inquiries will be presented to the Main Committee for appropriate action. The action of the Main Committee becomes effective only after confirmation by letter ballot of the Committee and approval by ASME.

Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute and published in *Mechanical Engi-*

[1] *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and pressure relief.

neering to invite comments from all interested persons. After the allotted time for public review and final approval by ASME, revisions are published annually in Addenda to the Code.

Code Cases may be used in the construction of components to be stamped with the ASME Code symbol beginning with the date of their approval by ASME.

After Code revisions are approved by ASME, they may be used beginning with the date of issuance shown on the Addenda. Revisions, except for revisions to material specifications in Section II, Parts A and B, become mandatory 6 months after such date of issuance, except for boilers or pressure vessels contracted for prior to the end of the 6 month period. Revisions to material specifications are originated by the American Society for Testing and Materials (ASTM), and other recognized national or international organizations and are usually adopted by ASME. However, those revisions may or may not have any effect on the suitability of material, produced to earlier editions of specifications, for use in ASME construction. ASME material specifications approved for use in each construction Code are listed in the Appendices of Section II, Parts A and B. These Appendices list, for each specification, the latest edition adopted by ASME, and earlier and later editions considered by ASME to be identical for ASME construction.

Manufacturers and users of components are cautioned against making use of revisions and Cases that are less restrictive than former requirements without having assurance that they have been accepted by the proper authorities in the jurisdiction where the component is to be installed.

Each state and municipality in the United States and each province in Canada that adopts or accepts one or more Sections of the Boiler and Pressure Vessel Code is invited to appoint a representative to act on the Conference Committee to the Boiler and Pressure Vessel Committee. Since the members of the Conference Committee are in active contact with the administration and enforcement of the rules, the requirements for inspection in this Code correspond with those in effect in their respective jurisdictions. The required qualifications for an Authorized Inspector under these rules may be obtained from the administrative authority of any state, municipality, or province which has adopted these rules.

The Boiler and Pressure Vessel Committee in the formulation of its rules and in the establishment of maximum design and operating pressures considers materials, construction, methods of fabrication, inspection, and safety devices. Permission may be granted to regulatory bodies and organizations publishing safety standards to use a complete Section of the Code by reference. If usage of a Section, such as Section IX, involves exceptions, omissions, or changes in provisions, the intent of the Code might not be attained.

Where a state or other regulatory body, in the printing of any Section of the Boiler and Pressure Vessel Code, makes additions or omissions, it is recommended that such changes be clearly indicated.

The National Board of Boiler and Pressure Vessel Inspectors is composed of chief inspectors of states and municipalities in the United States and of provinces in Canada that have adopted the Boiler and Pressure Vessel Code. This Board, since its organization in 1919, has functioned to uniformly administer and enforce the rules of the Boiler and Pressure Vessel Code. The cooperation of that organization with the Boiler and Pressure Vessel Committee has been extremely helpful.

The Code Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The Scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules. Laws or regulations issued by municipality, state, provincial, federal, or other enforcement or regulatory bodies having jurisdiction at the location of an installation establish the mandatory applicability of the Code rules, in whole or in part, within their jurisdiction. Those laws or regulations may require the use of this Code for vessels or components not considered to be within its Scope or may establish additions or deletions in that Scope. Accordingly, inquiries regarding such laws or regulations are to be directed to the issuing enforcement or regulatory body.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed to the ASME Boiler and Pressure Vessel Committee. ASME is to be notified should questions arise concerning improper use of an ASME Code symbol.

The specifications for materials given in Section II are identical with or similar to those of the Specifications published by ASTM, AWS, and other recognized national or international organizations. When reference is made in an ASME material specification to a non-ASME specification for which a companion ASME specification exists, the reference shall be interpreted as applying to the ASME material specification. Not all materials included in the material specifications in Section II have been adopted for Code use. Usage is limited to those materials and grades adopted by at least one of the other Sections of the Code for application under rules of that Section. All materials allowed

by these various Sections and used for construction within the scope of their rules shall be furnished in accordance with material specifications contained in Section II or referenced in Appendices A of Section II, Parts A and B except where otherwise provided in Code Cases or in the applicable Section of the Code. Materials covered by these specifications are acceptable for use in items covered by the Code Sections only to the degree indicated in the applicable Section. Materials for Code use should preferably be ordered, produced, and documented on this basis; Appendix A to Section II, Part A and Appendix A to Section II, Part B list editions of ASME and year dates of specifications that meet ASME requirements and which may be used in Code construction. Material produced to an acceptable specification with requirements different from the requirements of the corresponding specifications listed in Appendix A of Part A or Part B may also be used in accordance with the above, provided the material manufacturer or vessel manufacturer certifies with evidence acceptable to the Authorized Inspector that the corresponding requirements of specifications listed in Appendix A of Part A or Part B have been met. Material produced to an acceptable material specification is not limited as to country of origin.

When required by context in this Section, the singular shall be interpreted as the plural, and vice-versa; and the feminine, masculine, or neuter gender shall be treated as such other gender as appropriate.

Publication of the SI (Metric) Edition of the ASME Boiler and Pressure Vessel Code was discontinued with the 1986 Edition. Effective October 1, 1986, the SI Edition was withdrawn as an ASME Boiler and Pressure Vessel Code document.

STATEMENT OF POLICY ON THE USE OF CODE SYMBOLS AND CODE AUTHORIZATION IN ADVERTISING

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use Code Symbols for marking items or constructions which have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the Code Symbols for the benefit of the users, the enforcement jurisdictions, and the holders of the symbols who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the symbols, Certificates of Authorization, and reference to Code construction. The American Society of Mechanical Engineers does not "approve," "certify," "rate," or "endorse" any item, construction, or activity and there shall be no statements or implications which might so indicate. An organization holding a Code Symbol and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities "are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code," or "meet the requirements of the ASME Boiler and Pressure Vessel Code."

The ASME Symbol shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of a Code Symbol who may also use the facsimile in advertising to show that clearly specified items will carry the symbol. General usage is permitted only when all of a manufacturer's items are constructed under the rules.

The ASME logo, which is the cloverleaf with the letters ASME within, shall not be used by any organization other than ASME.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the official Code Symbol Stamp described in the governing Section of the Code.

Markings such as "ASME," "ASME Standard," or any other marking including "ASME" or the various Code Symbols shall not be used on any item which is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME which tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

GUIDELINE ON THE APPROVAL OF NEW MATERIALS UNDER THE ASME BOILER AND PRESSURE VESSEL CODE

Code Policy. It is the policy of the ASME Boiler and Pressure Vessel Committee to adopt for inclusion in Section II, only such specifications as have been adopted by the American Society for Testing and Materials (ASTM), by the American Welding Society (AWS), and by other recognized national or international organizations.

It is expected that requests for Code approval will normally be for materials for which there is a recognized national or international specification. For materials made to a recognized national or international specification other than those of ASTM or AWS, the inquirer shall give notice to the standards developing organization that a request has been made to ASME for adoption of their specification under the ASME Code. For other materials, a request shall be made to ASTM, AWS, or a recognized national or international organization to develop a specification that can be presented to the Code Committee.

It is the policy of the ASME Boiler and Pressure Vessel Committee to consider requests to adopt new materials only from boiler, pressure vessel, or nuclear power plant component Manufacturers or end users. Further, such requests should be for materials for which there is a reasonable expectation of use in a boiler, pressure vessel, or nuclear power plant component constructed to the rules of one of the Sections of this Code.

Application. The inquirer shall identify to the Committee the Section or Sections and Divisions of the Code in which the new material is to be incorporated, the temperature range of application, whether cyclic service is to be considered, and whether external pressure service is to be considered. The inquirer shall identify all product forms, size ranges, and specifications for which incorporation is desired.

The inquirer shall state whether or not the material is covered by patents, whether or not it is licensed, and if licensed, any limitations on its manufacture.

Mechanical Properties. Together with the specification for the material, the inquirer shall furnish the Committee with adequate data on which to base design values for inclusion in the applicable tables. The data shall include values of ultimate tensile strength, yield strength, reduction of area, and elongation, at 100°F (or 50°C) intervals, from room temperature to 100°F (or 50°C) above the maximum intended use temperature, unless the maximum intended use temperature does not exceed 100°F. If adoption is desired at temperatures at which time-dependent behavior may be expected to control design values, data on these time-independent properties shall be provided to a temperature 100°F (50°C) above the temperature at which time-dependent behavior becomes significant. Any heat treatment that is required to produce the tensile properties should be fully described.

If coverage is desired at temperatures at which time-dependent behavior may be expected, creep rate and creep rupture strength data of base metal and appropriate weld metals and weldments shall also be provided, at 100°F (or 50°C) intervals to 100°F (or 50°C) above the maximum intended use temperature.

If adoption at temperatures below room temperature is requested, and if it is desired to take design advantage of increased strength at lower temperatures, data on the time-independent properties shall be provided at 100°F (or 50°C) intervals to and including the lowest intended use temperature.

Notch toughness data shall be provided for materials for which Code toughness rules would be expected to apply. The data shall include test results for the intended lowest service metal temperature and for the range of material thicknesses desired. For welded construction, the notch toughness data shall include the results of Code toughness tests for weld metal and heat-affected zone for weldments made by the intended welding processes.

If the material is to be used in components that operate under external pressure, stress–strain curves (tension or compression) shall be furnished, at 100°F (or 50°C) intervals over the range of design temperatures desired. External pressure charts are based on the early portion (up to 1% strain) of the stress–strain curve. The stress–strain curve (not load versus extension) shall be determined using a Class B-2 or better accuracy extensometer as defined in ASTM E 83. Numerical data, when available, should be submitted. The data should include the original cross-sectional area of the test specimen and stress–strain curves with units marked on them.

If the material is to be used in cyclic service and the construction Code in which adoption is desired requires explicit consideration of cyclic behavior, fatigue data shall also be furnished over the range of design temperatures desired.

In general, for all mechanical properties, data shall be provided from at least three heats of material meeting all of the requirements of a specification for at least one product form for which adoption is desired, for each test at each test temperature. When adoption for both cast and wrought product forms is desired, data from at least three heats each of a wrought and of a cast product form shall be submitted. It is desired that the data represent all product forms for which adoption is desired. For product forms for which the properties may be size dependent, data from products of different sizes, including the largest size for which adoption is desired, shall be provided.

Test methods employed shall be those referenced in or by the material specifications, or shall be appropriate ASTM test methods or recommended practices for the properties tested.

Information describing service experience in the temperature range contemplated will be useful to the Committee.

Other Properties. The inquirer shall furnish to the Committee adequate data necessary to establish values for coefficient of thermal expansion, thermal conductivity and diffusivity, Young's modulus, shear modulus, and Poisson's ratio, when the construction Code in which adoption is desired requires explicit consideration of these properties. Data shall be provided over the range of temperatures for which the material is to be used.

Weldability. The inquirer shall furnish complete data on the weldability of material intended for welding, including data on procedure qualification tests made in accordance with the requirements of Section IX. Welding tests shall be made over the full range of thickness in which the material is to be used. Pertinent information, such as postweld heat treatment required, susceptibility to air hardening, effect of welding procedure and heat-affected zone and weld metal notch toughness, and the amount of experience in welding the material shall be given.

Physical Changes. For new materials, it is important to know the structural stability characteristics and the degree of retention of properties with exposure at temperature. The influence of fabrication practices, such as forming, welding, and thermal treatment, on the mechanical properties, ductility, and microstructure of the material are important, particularly where degradation in properties may occur. Where particular temperature ranges of exposure or heat treatment, cooling rates, combinations of mechanical working and thermal treatments, fabrication practices, exposure to particular environments, etc., cause significant changes in the mechanical properties, microstructure, resistance to brittle fracture, etc., it is of prime importance to call attention to those conditions that should be avoided in service or in manufacture of parts or vessels from the material.

Requests for Additional Data. The Committee may request additional data, including data on properties or material behavior not explicitly treated in the construction Code in which adoption is desired.

Code Case. The Code Committee will consider the issuance of an ASME Code Case, to be effective for a period of 3 years, permitting the use of a new material, provided that the following conditions are met:

(a) the inquirer provides evidence that a request for coverage of the material in a specification has been made to ASTM or a recognized national or international organization;

(b) the material is commercially available and can be purchased within the proposed specification requirements;

(c) the inquirer shows that there will be a reasonable demand for the material by industry and that there exists an urgency for approval by means of a Code Case;

(d) the requests for approval of the material shall clearly describe it in specification form, including such items as scope, process, manufacture, conditions for delivery, heat treatment, chemical and tensile requirements, forming properties, testing specifications and requirements, workmanship, finish, marking, inspection, and rejection;

(e) all other requirements identified previously under Code Policy and Application apply; and

(f) the inquirer shall furnish the Code Committee with all the data specified in this Appendix.

PERSONNEL

ASME Boiler and Pressure Vessel Committee
Subcommittees, Subgroups, and Working Groups

As of January 1, 1999

MAIN COMMITTEE

D. A. Canonico, *Chair*
G. G. Karcher, *Vice Chair*
J. S. Brzuszkiewicz, *Secretary*
R. W. Barnes
F. P. Barton
D. L. Berger
M. D. Bernstein
M. N. Bressler
J. R. Farr
R. E. Feigel
J. G. Feldstein
M. Gold
O. F. Hedden
A. J. Justin
D. F. Landers
W. M. Lundy
J. R. MacKay
T. J. Mawson
T. G. McCarty
G. C. Millman
R. A. Moen
C. C. Neely
T. P. Pastor
C. J. Pieper
R. F. Reedy
B. W. Roberts
F. J. Schaaf, Jr.
A. Selz
K. K. Tam
D. E. Tanner

EXECUTIVE COMMITTEE (MAIN COMMITTEE)

G. G. Karcher, *Chair*
D. A. Canonico, *Vice Chair*
J. S. Brzuszkiewicz, *Secretary*
J. G. Feldstein
M. Gold
O. F. Hedden
A. J. Justin
T. P. Pastor

HONORARY MEMBERS (MAIN COMMITTEE)

R. D. Bonner
R. J. Bosnak
H. M. Canavan
L. J. Chockie
J. S. Clarke
W. E. Cooper
W. D. Doty
R. C. Griffin
E. J. Hemzy
E. C. Kistner, Jr.
J. E. Lattan
J. LeCoff
F. N. Moschini
W. E. Somers
L. P. Zick, Jr.

HONORS AND AWARDS COMMITTEE

J. R. MacKay, *Chair*
A. J. Spencer, *Vice Chair*
C. Collado, *Secretary*
F. P. Barton
W. J. Carter
J. G. Feldstein
M. Gold
F. E. Gregor
E. C. Kistner, Jr.
T. P. Pastor
R. F. Reedy

MARINE CONFERENCE GROUP

J. Tiratto, *Chair*
L. W. Douthwaite
J. L. Jones
G. F. Wright

CONFERENCE COMMITTEE

D. E. Tanner — Tennessee *(Chair)*
R. D. Reetz — North Dakota *(Vice Chair)*
A. J. Justin — Ohio *(Secretary)*
R. J. Aben, Jr. — Michigan
J. S. Aclaro — Los Angeles, California
E. A. Anderson — Chicago, Illinois
J. Anderson — South Dakota
R. Barkdoll — Washington
F. P. Barton — Virginia
M. Bishop — British Columbia, Canada
D. E. Burns — Nebraska
C. Castle — Nova Scotia, Canada
R. R. Cate — Louisiana
L. Chase — Northwest Territories, Canada
R. A. Coomes — Kentucky
J. Corcoran — Connecticut
M. H. Diehl, Jr. — Maryland
D. A. Douin — Illinois
D. Eastman — Newfoundland and Labrador, Canada
G. L. Ebeyer — New Orleans, Louisiana
E. Everett — Georgia
P. C. Hackford — Utah
D. H. Hanrath — North Carolina
J. B. Harlan — Delaware
K. Hynes — Prince Edward Island, Canada
D. T. Jagger — Ohio
D. J. Jenkins — Kansas
M. Kotb — Quebec, Canada
J. P. Larson — Minnesota
K. T. Lau — Alberta, Canada
J. Lemire — California
W. C. Lundine — Oregon
S. E. Lyons — Arkansas
M. A. Malek — Florida
G. F. Mankel — Alaska
I. W. Mault — Manitoba, Canada
H. T. McEwen — Mississippi
A. W. Meiring — Indiana
R. Mile — Ontario, Canada
T. J. Monroe — Oklahoma
M. F. Mooney — Massachusetts
Y. Nagpaul — Hawaii
J. D. Payton — Pennsylvania
D. K. Peetz — Missouri
M. R. Peterson — Alaska
D. C. Price — Yukon Territory, Canada
R. S. Pucek — Wisconsin
T. E. Rennie — Arizona
M. Shuff — West Virginia
R. Snyder — New Jersey
N. Surtees — Saskatchewan, Canada
M. J. Verhagen — Wisconsin
R. B. West — Iowa
M. J. Wheel — Vermont
R. K. White — New York
T. F. Wickham — Rhode Island
C. S. Withers — Colorado

SUBCOMMITTEE ON POWER BOILERS (SC I)

J. R. MacKay, *Chair*
M. D. Bernstein, *Vice Chair*
P. D. Stumpf, *Secretary*
D. L. Berger
E. Everett
D. N. French
F. R. Gerety
J. Hainsworth
T. E. Hansen
J. S. Hunter
W. L. Lowry
T. C. McGough
R. E. McLaughlin
P. A. Molvie
D. K. Parrish
J. T. Pillow
R. G. Presnak
B. W. Roberts
R. D. Schueler, Jr.
R. V. Wielgoszinski
R. L. Williams

Subgroup on Design (SC I)

M. D. Bernstein, *Chair*
R. D. Schueler, Jr., *Vice Chair*
P. A. Molvie, *Secretary*
M. L. Coats
J. D. Fishburn
C. F. Jeerings
K. C. Morrison
N. Surtees
R. V. Wielgoszinski

Subgroup on Fabrication and Examination (SC I)

D. L. Berger, *Chair*
R. E. McLaughlin, *Secretary*
R. W. Boyce
D. N. French
J. Hainsworth
T. E. Hansen
M. H. Iken
J. M. Lyons
J. T. Pillow
M. E. Reese
R. D. Schueler, Jr.
R. F. Slack, Sr.

Subgroup on General Requirements (SC I)

T. C. McGough, *Chair*
M. D. Bernstein, *Vice Chair*
W. L. Lowry, *Secretary*
D. L. Berger
E. Everett
F. R. Gerety
J. Hainsworth
C. F. Jeerings
J. M. Lyons
R. E. McLaughlin
D. K. Parrish
J. T. Pillow
W. E. Somers
R. L. Williams

Subgroup on Materials (SC I)

B. W. Roberts, *Chair*
C. E. Spaeder, Jr., *Chair*
J. S. Hunter, *Secretary*
D. N. French
J. F. Henry
J. P. Libbrecht
F. Masuyama
J. M. Tanzosh
H. N. Titer, Jr.

Subgroup on Piping (SC I)

T. E. Hansen, *Chair*
D. L. Berger
M. D. Bernstein
P. D. Edwards
M. H. Iken
W. L. Lowry
T. C. McGough
R. G. Presnak
E. Whittle

SUBCOMMITTEE ON MATERIALS (SC II)

M. Gold, *Chair*
R. A. Moen, *Vice Chair*
F. R. Lyons, *Secretary*
A. P. Ahrendt
M. N. Bressler
J. Cameron
A. Cohen
R. Dirscherl
W. D. Doty
W. D. Edsall
D. W. Gandy
M. H. Gilkey
J. J. Heger
J. F. Henry
C. L. Hoffmann
G. C. Hsu
F. Masuyama
R. K. Nanstad
E. G. Nisbett
J. T. Parsons
D. W. Rahoi
B. W. Roberts
E. Shapiro
C. E. Spaeder, Jr.
R. W. Swindeman
J. M. Tanzosh
R. S. Vecchio
A. W. Zeuthen

Subgroup on External Pressure (SC II)

R. W. Mikitka, *Chair*
D. J. Green, *Secretary*
D. C. Agarwal
D. S. Griffin
M. Katcher
E. Michalopoulos
B. R. Morelock
D. Nadel
C. E. Spaeder, Jr.
C. H. Sturgeon

Subgroup on Ferrous Specifications (SC II)

E. G. Nisbett, *Chair*
B. M. Dingman
W. D. Edsall
T. Graham
W. N. Holliday
D. A. Jackson
E. A. Jonas
D. C. Krouse
J. F. Longenecker
W. C. Mack
A. S. Melilli
J. T. Parsons
E. J. Rozic, Jr.
E. Upitis
R. H. Zong

Subgroup on International Material Specifications (SC II)

J. T. Parsons, *Chair*
R. R. Seeley, *Secretary*
D. C. Agarwal
J. Cameron
R. Dirscherl
W. D. Doty
D. M. Fryer
M. Gold
M. H. Iken
W. M. Lundy
H. Masahisa
T. F. Miskell
F. Osweiller
A. P. Povilonis
R. D. Schueler, Jr.
E. A. Steen
E. Upitis
E. O. Woolridge

Subgroup on Nonferrous Alloys (SC II)

D. W. Rahoi, *Chair*
D. C. Agarwal, *Secretary*
W. R. Apblett, Jr.
L. G. Coffee
A. Cohen
R. Dirscherl
M. H. Gilkey
B. Heuer
G. C. Hsu
M. Katcher
A. G. Kireta, Jr.
E. Shapiro
L. E. Shoemaker
R. C. Sutherlin

Subgroup on Strength, Ferrous Alloys (SC II)

B. W. Roberts, *Chair*
J. M. Tanzosh, *Secretary*
A. P. Ahrendt
W. R. Apblett, Jr.
T. M. Cullen
M. Gold
J. J. Heger
C. L. Hoffmann
A. Iseda
F. Masuyama
R. A. Moen
D. W. Rahoi
C. E. Spaeder, Jr.
R. W. Swindeman
B. E. Thurgood

Subgroup on Strength of Weldments (SC II & SC IX)

C. E. Spaeder, Jr., *Chair*
C. Robino, *Secretary*
W. D. Doty
D. W. Rahoi
B. W. Roberts
W. J. Sperko
J. M. Tanzosh
B. E. Thurgood

Subgroup on Toughness (SC II)

R. S. Vecchio, *Chair*
J. M. Barsom
D. A. Hansen
R. K. Nanstad
A. Selz
S. Yukawa
R. Zawierucha

SUBCOMMITTEE ON NUCLEAR POWER (SC III)

C. J. Pieper, *Chair*
R. M. Jessee, *Vice Chair*
C. A. Sanna, *Secretary*
J. P. Allen III
Y. Asada
R. W. Barnes
J. N. Baysden
W. H. Borter
E. B. Branch
M. N. Bressler
F. C. Cherny
G. D. Cooper
R. P. Deubler
W. D. Doty
F. R. Drahos
K. Ennis
B. A. Erler
D. H. Hanrath
C. L. Hoffmann
K.-H. Hsu
D. F. Landers
W. C. LaRochelle
W. N. McLean
R. A. Moen
D. B. Nickerson
R. F. Perrin
R. F. Reedy
M. W. Smith
J. D. Stevenson
R. E. Tome
K. R. Wichman

Subgroup on Containment Systems for Spent Fuel and High-Level Waste Transport Packagings (SC III)

J. D. Stevenson, *Chair*
H. H. Chung
R. R. Doggart
E. L. Farrow
G. M. Foster
K. Goldmann
D. R. Heath
R. H. Jones
W. H. Lake
H. W. Lee
P. McConnell
T. J. Neider
R. E. Nickell
D. J. Nolan
D. T. Raske
T. Saegusa
R. H. Smith
G. J. Solovey
K. B. Sorenson
C. J. Temus
P. Turula
N. Urabe
C. R. Witt
M. Witte
S. Yukawa

Subgroup on Design (SC III)

R. W. Barnes, *Chair*
E. B. Branch, *Vice Chair*
R. S. Hill III, *Secretary*
Y. Asada
M. N. Bressler
C. W. Bruny
J. R. Cole
G. D. Cooper
R. P. Deubler
R. E. Gimple
D. H. Hanrath
R. W. Haupt
T. Iida
B. Jarman
J. T. Land
D. F. Landers
W. N. McLean
D. B. Nickerson
E. C. Rodabaugh
J. R. Santangelo
G. C. Slagis
J. D. Stevenson
J. H. Wawrzeniak
K. R. Wichman
R. Wray

Working Group on Administration (SG-D) (SC III)

E. B. Branch, *Chair*
R. W. Barnes, *Vice Chair*
R. S. Hill III, *Secretary*
C. W. Bruny
G. D. Cooper
R. P. Deubler
J. T. Land
D. F. Landers
W. N. McLean
D. B. Nickerson
J. R. Santangelo
R. Wray

Working Group on Component Supports (SG-D) (SC III)

R. P. Deubler, *Chair*
R. M. Dulin, Jr., *Secretary*
U. S. Bandyopadhyay
F. J. Birch
M. N. Bressler
J. R. Cole
J. C. Finneran, Jr.
R. W. Haupt
J. C. Hennart
A. S. Laurenson
A. Lee
R. J. Masterson
A. N. Nguyen
J. R. Stinson

Working Group on Core Support Structures (SG-D) (SC III)

R. H. Hansen
K. B. Larsen
J. F. Mullooly
B. L. Silverblatt

Working Group on Dynamic and Extreme Load Conditions (SG-D) (SC III)

R. Wray, *Chair*
A. E. Meligi, *Secretary*
P. L. Anderson
M. K. Au-Yang
R. D. Blevins
G. J. Bohm
D. L. Caldwell
P.-Y. Chen
A. Hadjian
M. Hartzman
W. S. LaPay
H. Lockert
P. R. Olson
R. F. Perry
J. Wallach

Working Group on Piping (SG-D) (SC III)

D. F. Landers, *Chair*
R. S. Hill III, *Vice Chair*
P. Hirschberg, *Secretary*
T. M. Adams
G. A. Antaki
J. R. Cole
A. B. Glickstein
R. W. Haupt
J. C. Hennart
R. D. Hookway
R. B. Jenkins
K. A. Manoly
J. C. Minichiello
S. E. Moore
A. N. Nguyen
O. O. Oyamada
R. D. Patel
E. C. Rodabaugh
J. R. Santangelo
M. S. Sills
G. C. Slagis
E. A. Wais

Working Group on Pumps (SG-D) (SC III)

D. B. Nickerson, *Chair*
H. L. Brammer
P. Burchett
R. E. Cornman, Jr.
A. A. Fraser
M. Higuchi
G. R. Jones
J. W. Leavitt
J. E. Livingston
R. A. Schussler
H. Tafarrodi
G. K. Vaghasia

Working Group on Valves (SG-D) (SC III)

W. N. McLean, *Chair*
E. A. Bake
R. R. Brodin
W. G. Knecht
R. Koester
J. J. McGavin
J. D. Page
S. N. Shields
H. R. Sonderegger
J. C. Tsacoyeanes
R. G. Visalli

Working Group on Vessels (SG-D) (SC III)

C. W. Bruny, *Chair*
T. K. Burr, Sr.
G. D. Cooper
G. A. Deaver
D. H. Hanrath
W. J. Heilker
B. Jarman
T. M. Khan
O. Maekawa
K. A. Manoly
D. E. Matthews
A. Merend
G. K. Miller
W. Z. Novak
E. Pelling
H. S. Thornton

Special Working Group on Environmental Effects (SG-D) (SC III)

W. Z. Novak, *Chair*
Y. Asada
W. J. Heilker
R. S. Hill III
C. L. Hoffmann
R. A. Moen
S. Yukawa

Special Working Group on Seismic Piping Rules (SG-D) (SC III)

E. B. Branch, *Chair*
T. M. Adams
G. A. Antaki
R. D. Hookway
T. Isogai
H. Kobayashi
J. C. Minichiello
M. S. Sills
E. A. Wais
T. Yamazaki

Subgroup on General Requirements (SC III & SC 3C)

W. C. LaRochelle, *Chair*
K. Ennis, *Secretary*
A. Appleton
J. R. Barbee
J. N. Baysden
B. H. Berg
R. E. Kelley
G. S. Korin
C. Lizotte
M. J. Meyer
R. D. Miles
M. R. Minick
L. C. Oakes
R. F. Perrin
B. B. Scott
D. E. Tanner
D. M. Vickery
D. V. Walshe

Subgroup on Materials, Fabrication, and Examination (SC III)

C. L. Hoffmann, *Chair*
G. P. Milley, *Secretary*
C. W. Allison
W. H. Borter
D. Doyle
F. R. Drahos
G. M. Foster
G. B. Georgiev
J. E. Harris
R. W. Jackson
R. M. Jessee
C. C. Kim
R. A. Moen
H. Murakami
C. J. Pieper
R. R. Seeley
N. M. Simpson
R. C. Soin
W. J. Sperko
K. B. Stuckey
S. Yukawa

Subgroup on Pressure Relief (SC III)

F. C. Cherny, *Chair*
S. F. Harrison, Jr.
E. M. Petrosky
M. W. Smith
A. L. Szeglin
B. S. York
J. R. Zahorsky

Special Working Group on Editing and Review (SC III)

R. F. Reedy, *Chair*
W. H. Borter
M. N. Bressler
R. P. Deubler
B. A. Erler
W. C. LaRochelle
M. W. Smith
J. D. Stevenson
E. O. Woolridge

JOINT ACI-ASME COMMITTEE ON CONCRETE COMPONENTS FOR NUCLEAR SERVICE (SC 3C)

B. A. Erler, *Chair*
C. A. Sanna, *Secretary*
J. P. Allen III
J. F. Artuso
R. M. Attar
S. Bhuyan
A. C. Eberhardt
D. J. Haavik
M. F. Hessheimer
D. C. Jeng
T. E. Johnson
S. F. Putman
B. B. Scott
R. E. Shewmaker
J. D. Stevenson
A. Y. Wong

Subgroup on Design (SC 3C)

D. G. Adams
A. C. Eberhardt
T. E. Johnson
S. F. Putman
R. E. Shewmaker
J. D. Stevenson
A. Y. Wong

Subgroup on Materials, Construction, and Examination (SC 3C)

D. J. Haavik, *Chair*
J. F. Artuso
R. M. Attar
B. A. Erler
J. Gutierrez

SUBCOMMITTEE ON HEATING BOILERS (SC IV)

F. P. Barton, *Chair*
P. A. Molvie, *Vice Chair*
B. P. Feder, *Secretary*
R. B. Duggan
W. L. Haag, Jr.
W. M. Hiddleston
J. D. Hoh
K. M. McTague
R. I. Mullican
E. A. Nordstrom
J. L. Seigle
D. E. Tanner
S. V. Voorhees
R. H. Weigel
R. V. Wielgoszinski
J. I. Woodworth
T. L. Bedeaux, *Alternate*

Subgroup on Care and Operation of Heating Boilers (SC IV)

J. I. Woodworth, *Chair*
B. P. Feder, *Secretary*
K. J. Hoey
J. D. Hoh
K. M. McTague
P. A. Molvie
R. I. Mullican
R. H. Weigel
T. F. Wickham
T. L. Bedeaux, *Alternate*

Subgroup on Cast Iron Boilers (SC IV)

K. M. McTague, *Chair*
R. B. Duggan
R. H. Weigel
T. F. Wickham
J. I. Woodworth
T. L. Bedeaux, *Alternate*

Subgroup on Water Heaters (SC IV)

W. L. Haag, Jr., *Chair*
T. D. Gantt
W. M. Hiddleston
K. M. McTague
R. I. Mullican
D. Smith
D. E. Tanner
M. A. Taylor

Subgroup on Welded Boilers (SC IV)

P. A. Molvie, *Chair*
T. L. Bedeaux
D. H. Mapes
E. A. Nordstrom
J. L. Seigle
R. F. Slack, Sr.
R. P. Sullivan
D. E. Tanner
R. V. Wielgoszinski

SUBCOMMITTEE ON NONDESTRUCTIVE EXAMINATION (SC V)

T. G. McCarty, *Chair*
J. E. Batey, *Vice Chair*
F. S. Fitzgerald, *Secretary*
A. S. Birks
B. H. Clark, Jr.
W. T. Clayton
R. A. Coomes
N. Y. Faransso
H. C. Graber
O. F. Hedden
G. W. Hembree
F. B. Kovacs
J. F. Manning
W. C. McGaughey
R. D. McGuire

Subgroup on General Requirements/Personnel Qualifications and Inquiries (SC V)

R D. McGuire, *Chair*
J. E. Batey
W. T. Clayton
N. Y. Faransso
H. C. Graber
G. W. Hembree
J. R. MacKay
J. P. Swezy

Subgroup on Surface Examination Methods (SC V)

H. C. Graber, *Chair*
S. J. Akrin
T. Alexander
A. S. Birks
B. H. Clark, Jr.
R. A. Coomes
G. W. Hembree

Subgroup on Volumetric Methods (SC V)

J. E. Batey, *Chair*
S. J. Akrin
W. T. Clayton
N. Y. Faransso
H. C. Graber
G. W. Hembree
B. Kellerhall
E. K. Kietzman
F. B. Kovacs
R. W. Kruzic
J. F. Manning
W. C. McGaughey
J. R. Mitchell

Working Group on Acoustic Emissions (SG-VM) (SC V)

B. H. Clark, Jr.
P. M. Horrigan
J. F. Manning
J. R. Mitchell

Working Group on Radiography (SG-VM) (SC V)

G. W. Hembree, *Chair*
S. J. Akrin
T. Alexander
J. E. Batey
N. Y. Faransso
H. C. Graber
F. B. Kovacs

Working Group on Ultrasonics (SG-VM) (SC V)

W. T. Clayton, *Chair*
O. F. Hedden
B. Kellerhall
E. K. Kietzman
J. F. Manning
W. C. McGaughey
R. Paillaman
F. J. Sattler
M. L. Shakinovsky

SUBCOMMITTEE ON PRESSURE VESSELS (SC VIII)

T. P. Pastor, *Chair*
K. Mokhtarian, *Vice Chair*
A. J. Roby, *Secretary*
A. P. Ahrendt
V. Bogosian
S. M. Caldwell
S. C. Cyr
R. Dirscherl
R. M. Elliott
J. R. Farr
R. E. Feigel
J. G. Feldstein
G. L. Hollinger
M. J. Houle
W. S. Jacobs
G. G. Karcher
J. C. Keenan
G. B. Komora
K. T. Lau
R. W. Mikitka
U. R. Miller
C. C. Neely
M. D. Rana
K. J. Schneider
A. Selz
J. R. Sims, Jr.
A. J. Spencer
E. A. Steen
K. K. Tam
E. L. Thomas, Jr.

Subgroup on Design (SC VIII)

U. R. Miller, *Chair*
R. E. Knoblock, *Secretary*
M. R. Bauman
M. R. Breach
S. M. Caldwell
J. R. Farr
J. A. Hayward
G. L. Hollinger
W. S. Jacobs
G. G. Karcher
G. B. Komora
R. W. Mikitka
K. Mokhtarian
T. P. Pastor
M. D. Rana
A. Selz
S. C. Shah
J. W. Stokes
K. K. Tam
E. L. Thomas, Jr.

Subgroup on Fabrication and Inspection (SC VIII)

E. A. Steen, *Chair*
J. L. Arnold
W. J. Bees
R. W. Boyce
S. C. Cyr
R. E. Feigel
H. E. Gordon
M. J. Houle
K. M. Hudson
W. S. Jacobs
R. A. Johnson
D. J. Kreft
A. S. Lester III
J. W. McEnerney
F. C. Ouyang
M. J. Pischke
M. J. Rice
C. D. Rodery
W. P. Webb

Subgroup on General Requirements (SC VIII)

R. M. Elliott, *Chair*
A. P. Ahrendt
V. Bogosian
W. P. Crow
J. P. Glaspie
C. R. Good
D. B. Kadakia
J. C. Keenan
K. T. Lau
W. E. Laveck, Jr.
A. S. Mann
C. C. Neely
A. S. Olivares
K. J. Schneider
A. J. Spencer
J. P. Swezy

Subgroup on Materials (SC VIII)

R. Dirscherl, *Chair*
D. C. Agarwal
A. P. Ahrendt
J. Cameron
W. D. Doty
W. D. Edsall
D. A. Franklin
B. Heuer
M. Katcher
W. M. Lundy
E. E. Morgenegg
E. G. Nisbett
J. T. Parsons
D. W. Rahoi
K. K. Tam
B. K. Thakur

Special Working Group on Heat Transfer Equipment (SC VIII)

G. B. Komora, *Chair*
R. P. Zoldak, *Secretary*
C. F. Andreone
S. M. Caldwell
M. J. Holtz
W. G. Jandrasits
R. Mahadeen
U. R. Miller
T. W. Norton
F. Osweiller
A. I. Soler
W. A. Treff
S. Yokell

Special Working Group on High-Pressure Vessels (SC VIII)

J. R. Sims, Jr., *Chair*
P. A. Reddington, *Secretary*
L. P. Antalffy
J. E. Baxter
R. C. Biel
T. B. Boyd
D. J. Burns
P. N. Chaku
E. L. Danfelt
R. E. Feigel
D. M. Fryer
J. L. Heck, Jr.
A. H. Honza
V. T. Hwang
M. M. James
P. Jansson
J. A. Kapp
D. P. Kendall
A. K. Khare
S. C. Mordre
G. J. Mraz
E. H. Perez
L. M. Picqueur
E. D. Roll
W. L. Stewart
J. F. Sullivan
F. W. Tatar

Special Working Group on Toughness (SC VIII)

W. S. Jacobs, *Chair*
J. Cameron
W. D. Doty
H. E. Gordon
G. G. Karcher
G. B. Komora
K. Mokhtarian
J. L. Mooney
C. C. Neely
M. D. Rana
J. W. Stokes

SUBCOMMITTEE ON WELDING (SC IX)

J. G. Feldstein, *Chair*
W. J. Sperko, *Vice Chair*
J. Labrador, *Secretary*
R. Barkdoll
D. A. Bowers
M. L. Carpenter
L. P. Connor
W. D. Doty
P. D. Flenner
M. J. Houle
R. A. Johnson
W. M. Lundy
R. D. McGuire
J. J. Meyer
A. H. Miller
B. R. Newmark
P. P. Norris
A. S. Olivares
S. D. Reynolds, Jr.
W. K. Scattergood
G. W. Spohn III
M. J. Stanko
P. L. Van Fosson
R. R. Young

Subgroup on Brazing (SC IX)

M. J. Houle, *Chair*
A. S. Artayet
M. L. Carpenter
C. F. Jeerings
A. H. Miller
M. J. Pischke
C. Robino

Subgroup on General Requirements (SC IX)

B. R. Newmark, *Chair*
R. Barkdoll
P. R. Evans
P. C. Filean
R. M. Jessee
D. W. Mann
A. S. Olivares
C. E. Wainwright
R. A. Weiss
K. R. Willens

Subgroup on Materials (SC IX)

M. L. Carpenter, *Chair*
L. P. Connor
P. D. Flenner
R. M. Jessee
A. H. Miller
H. A. Sadler
C. E. Sainz
C. E. Spaeder, Jr.
W. J. Sperko
M. J. Stanko
R. R. Young

Subgroup on Performance Qualification (SC IX)

J. J. Meyer, *Chair*
V. A. Bell
D. A. Bowers
L. P. Connor
R. A. Coomes
P. D. Flenner
G. Herrmann
M. J. Houle
W. M. Lundy
R. D. McGuire
S. R. Nordman
P. P. Norris
W. K. Scattergood
G. W. Spohn III

Subgroup on Procedure Qualification (SC IX)

J. J. Meyer, *Chair*
R. K. Brown, Jr.
R. A. Johnson
A. H. Miller
P. P. Norris
A. S. Olivares
F. C. Ouyang
S. D. Reynolds, Jr.
M. J. Rice
W. K. Scattergood
W. J. Sperko
P. L. Van Fosson
T. C. Wiesner

SUBCOMMITTEE ON FIBER-REINFORCED PLASTIC PRESSURE VESSELS (SC X)

P. J. Conlisk, *Chair*
D. Eisberg, *Vice Chair*
A. J. Roby, *Secretary*
K. M. Agrawal
F. L. Brown
J. L. Bustillos
T. W. Cowley
T. J. Fowler
L. E. Hunt
J. C. Murphy
A. L. Newberry
D. J. Painter
J. R. Richter
J. A. Rolston
B. F. Shelley
J. H. Skaggs
P. R. Wilt
D. O. Yancy

SUBCOMMITTEE ON NUCLEAR INSERVICE INSPECTION (SC XI)

O. F. Hedden, *Chair*
T. J. Mawson, *Vice Chair*
J. M. Saltarelli, *Secretary*
W. H. Bamford, Jr.
R. L. Beverly
J. M. Bloom
R. W. Boyce
C. D. Cowfer
D. D. Davis
R. L. Dyle
T. N. Epps III
R. E. Gimple
F. E. Gregor
K. Iida
R. D. Kerr
D. F. Landers
T. F. Lentz
J. T. Lindberg
G. C. Millman
C. R. Osman
P. C. Riccardella
A. T. Roberts III
L. Sage
F. J. Schaaf, Jr.
J. E. Staffiera
R. P. Sullivan
R. W. Swayne
C. W. Tahnk
R. J. Tamminga
R. A. Yonekawa

Honorary Members (SC XI)

S. H. Bush
L. J. Chockie
J. P. Houstrup
L. R. Katz
R. R. MacCary

Subgroup on Evaluation Standards (SC XI)

W. H. Bamford, Jr., *Chair*
M. Kupinski, *Secretary*
J. M. Bloom
R. C. Cipolla
R. M. Gamble
T. J. Griesbach
P. J. Hijeck
K. Iida
Y. Imamura
J. G. Merkle
S. Ranganath
P. C. Riccardella
D. A. Scarth
W. L. Server
C. A. Tomes
W. A. Van Der Sluys
K. R. Wichman
G. M. Wilkowski
K. K. Yoon
S. Yukawa

Working Group on Flaw Evaluation (SG-ES) (SC XI)

R. C. Cipolla, *Chair*
G. H. De Boo, *Secretary*
W. H. Bamford, Jr.
M. Basol
J. M. Bloom
E. Friedman
T. J. Griesbach
F. D. Hayes
D. N. Hopkins
K. Iida
Y. Imamura
M. Kupinski
H. S. Mehta
J. G. Merkle
J. S. Panesar
S. Ranganath
D. A. Scarth
T. S. Schurman
W. L. Server
F. A. Simonen
K. R. Wichman
G. M. Wilkowski
K. K. Yoon
S. Yukawa
A. Zahoor
V. A. Zilberstein

Working Group on Operating Plant Criteria (SG-ES) (SC XI)

T. J. Griesbach, *Chair*
W. H. Bamford, Jr.
H. Behnke
B. A. Bishop
W. F. Brady
E. Friedman
S. R. Gosselin
E. M. Hackett
P. J. Hijeck
M. Kupinski
S. D. Leshnoff
P. Manbeck
H. S. Mehta
J. S. Panesar
W. E. Pennell
S. Ranganath
S. T. Rosinski
W. L. Server
E. A. Siegel
F. A. Simonen
T. D. Spry
K. K. Yoon
S. Yukawa

Working Group on Pipe Flaw Evaluation (SG-ES) (SC XI)

D. A. Scarth, *Chair*
G. M. Wilkowski, *Secretary*
W. H. Bamford, Jr.
R. C. Cipolla
N. G. Cofie
S. K. Daftuar
G. H. De Boo
E. Friedman
D. N. Hopkins
K. Iida
H. S. Mehta
J. S. Panesar
K. K. Yoon
S. Yukawa
A. Zahoor
V. A. Zilberstein

Subgroup on Liquid-Metal–Cooled Systems (SC XI)

C. G. McCargar, *Chair*
W. L. Chase
S. Hattori
R. Hundal
R. W. King
W. Kwant

Working Group on Liquid-Metal Reactor Covers (SG-LMCS) (SC XI)

W. L. Chase, *Chair*
S. Hattori
R. Hundal
W. Kwant

Subgroup on Nondestructive Examination (SC XI)

N. R. Bentley, *Secretary*
D. C. Adamonis
F. L. Becker
F. T. Carr
C. B. Cheezem
W. T. Clayton
C. D. Cowfer
F. J. Dodd
T. N. Epps III
D. O. Henry
M. R. Hum
D. Lamond
S. N. Liu
R. D. McGuire
M. C. Modes
C. R. Osman
F. J. Schaaf, Jr.
J. C. Spanner, Jr.
C. J. Wirtz

Working Group on Personnel Qualification and Surface, Visual, and Eddy Current Examination (SG-NDE) (SC XI)

C. J. Wirtz, *Secretary*
B. L. Curtis
N. Economos
H. B. Garland
D. O. Henry
H. E. Houserman
J. J. McArdle III
R. D. McGuire
S. A. Redner
M. F. Sherwin
D. Spake
J. C. Spanner, Jr.
T. V. Tran

Working Group on Pressure Testing (SG-NDE) (SC XI)

G. P. Alexander
T. M. Anselmi
T. B. Basso
J. Boughman
T. R. Bugelholl
R. J. Cimoch
W. N. Keisler
D. Lamond
F. J. Schaaf, Jr.

Working Group on Procedure Qualification and Volumetric Examination (SG-NDE) (SC XI)

C. D. Cowfer, *Chair*
C. E. Larsen, *Secretary*
D. C. Adamonis
F. L. Becker
N. R. Bentley
B. Bevins
F. T. Carr
C. B. Cheezem
W. T. Clayton
S. R. Doctor
F. J. Dodd
T. N. Epps III
B. Kellerhall
G. A. Lofthus
J. K. McClanahan
M. C. Modes
M. Saporito
T. T. Taylor
S. M. Walker

Subgroup on Repairs, Replacements, and Modifications (SC XI)

R. E. Gimple, *Chair*
W. C. Holston, *Secretary*
R. W. Boyce
M. N. Bressler
R. E. Cantrell
C. E. Hartz
R. A. Hermann
R. D. Kerr
D. F. Landers
R. S. Lewis
T. J. Mawson
M. S. McDonald
R. R. Stevenson
R. P. Sullivan
R. W. Swayne
R. E. Tome
D. E. Waskey
R. A. Yonekawa

Working Group on Design Reconciliation (SG-RR&M) (SC XI)

W. C. Holston, *Chair*
J. T. Conner, *Secretary*
R. W. Boyce
S. B. Brown
T. E. Hiss
E. V. Imbro
D. N. Irvine, Jr.
D. F. Landers
R. W. Swayne
A. H. Taufique
H. J. Thailer
R. E. Tome

Working Group on Responsibilities and Program Requirements (SG-RR&M) (SC XI)

R. A. Yonekawa, *Chair*
R. R. Stevenson, *Secretary*
L. L. Campbell
S. K. Fisher
G. M. Foster
C. E. Hartz
R. S. Lewis
M. S. McDonald
S. M. Swilley
A. J. Walcutt
J. Ghergurovich, *Alternate*

Working Group on Welding and Special Repair Processes (SG-RR&M) (SC XI)

D. E. Waskey, *Chair*
R. E. Cantrell, *Secretary*
D. A. Delsignore
P. D. Fisher
A. J. Giannuzzi
R. A. Hermann
R. P. Indap
R. D. Kerr
B. R. Newton
P. P. Norris
J. E. O'Sullivan
J. H. Sodergren
K. R. Willens

Subgroup on Water-Cooled Systems (SC XI)

K. Christian, *Secretary*
W. J. Briggs
T. R. Bugelholl
D. D. Davis
A. F. Deardorff
R. L. Dyle
M. Herrera
T. C. Hinkle
S. D. Kulat
T. F. Lentz
J. T. Lindberg
M. P. Lintz
W. E. Norris
G. C. Park
C. Pendleton
J. E. Staffiera
C. W. Tahnk
R. J. Tamminga
E. Throckmorton
S. M. Walker
R. A. West

Working Group on Containment (SG-WCS) (SC XI)

J. E. Staffiera, *Chair*
W. E. Norris, *Secretary*
H. G. Ashar
W. J. Briggs
K. K. N. Chao
M. J. Ferlisi
R. W. Hammelmann
H. T. Hill
R. D. Hough
C. N. Krishnaswamy
M. P. Lintz
D. Naus
S. C. Petitgout
C. G. Ranganath
G. W. Robin
B. Talmadge
R. T. Zak

Working Group on Implementation of Risk-Based Examination (SG-WCS) (SC XI)

S. D. Kulat, *Chair*
T. J. Mawson, *Chair*
A. McNeill III, *Secretary*
J. Agold
S. A. Ali
B. A. Bishop
J. W. Connor
A. F. Deardorff
H. Q. Do
R. Fougerousse
S. R. Gosselin
M. R. Graybeal
J. T. Lindberg
I. Mach
R. K. Mattu
P. J. O'Regan
J. H. Phillips
F. A. Simonen
T. V. Vo
R. A. West

Working Group on Inspection of Systems and Components (SG-WCS) (SC XI)

E. Throckmorton, *Chair*
G. C. Park, *Secretary*
G. L. Belew
T. W. Brombach
H. Q. Do
R. Fougerousse
T. C. Hinkle
M. R. Hum
S. D. Kulat
J. T. Lindberg
T. K. McLellan
C. Pendleton
C. M. Ross
C. W. Tahnk
K. B. Thomas
R. A. West
J. Whitman

Working Group on General Requirements (SC XI)

A. T. Roberts III, *Chair*
R. G. Edl, *Secretary*
D. A. Graham
D. A. Jackson
R. K. Mattu
L. Sage
R. J. Scott
J. C. Shropshire
R. J. Tamminga

Special Working Group on Editing and Review (SC XI)

R. W. Swayne, *Chair*
R. L. Beverly
M. P. Lintz
J. E. Staffiera
C. J. Wirtz

Special Working Group on Plant Life Extension (SC XI)

F. E. Gregor, *Chair*
M. P. Lintz, *Secretary*
D. D. Davis
D. A. Graham
D. L. Harrison
P. Manbeck
H. W. Massie, Jr.
T. A. Meyer
D. W. Peltola
D. A. Piccione
C. M. Regan
V. N. Shah
R. J. Tamminga

SUBCOMMITTEE ON TRANSPORT TANKS (SC XII)

A. Selz, *Chair*
P. D. Stumpf, *Secretary*
A. N. Antoniou
S. C. Cyr
K. Ennis
M. Hennemand
C. H. Hochman
G. G. Karcher
P. P. Laluc
G. McRae
M. R. Minick
T. P. Pastor
M. D. Rana
C. M. Serratella
G. R. Stoeckinger
N. Surtees
J. P. Swezy
A. P. Varghese
S. V. Voorhees
W. L. White

Subgroup on Design and Materials (SC XII)

M. D. Rana, *Chair*
D. A. Canonico
W. D. Doty
G. G. Karcher
P. P. Laluc
T. P. Pastor
J. L. Rademacher
T. A. Rogers
C. M. Serratella
A. P. Varghese
E. Whittle

Subgroup on Fabrication and Inspection (SC XII)

S. V. Voorhees, *Chair*
M. Burch
D. A. Canonico
M. L. Coats
M. Hennemand
D. J. Kreft
G. McRae
M. R. Minick
N. Surtees
J. P. Swezy

Subgroup on General Requirements (SC XII)

C. H. Hochman, *Chair*
T. Alexander
A. N. Antoniou
D. Carter
K. Ennis
M. A. Garrett
K. L. Gilmore
J. C. Keenan
T. B. Lee
F. A. Licari
G. R. Stoeckinger
W. L. White
L. Wolpert

SUBCOMMITTEE ON BOILER AND PRESSURE VESSEL ACCREDITATION (SC-BPVA)

A. J. Spencer, *Chair*
A. J. Justin, *Vice Chair*
K. I. Baron, *Secretary*
M. B. Doherty
D. A. Douin
P. D. Edwards
R. M. Elliott
C. E. Ford
R. C. Howard
B. B. MacDonald
M. L. Sisk
B. C. Turczynski
R. L. Williams
V. A. Bell, *Alternate*
V. Bogosian, *Alternate*
M. A. De Vries, *Alternate*
R. G. Friend, *Alternate*
L. J. Kuchera, *Alternate*
W. C. LaRochelle, *Alternate*
A. S. Lester III, *Alternate*
K. M. McTague, *Alternate*
G. P. Milley, *Alternate*
P. G. Scheckermann, *Alternate*
N. Surtees, *Alternate*

SUBCOMMITTEE ON NUCLEAR ACCREDITATION (SC-NA)

T. E. Quaka, *Chair*
R. R. Stevenson, *Vice Chair*
S. Griffin, *Secretary*
M. N. Bressler
G. Deily
F. R. Drahos
J. E. Harris
M. Kotb
W. C. LaRochelle
R. P. McIntyre
H. B. Prasse
A. T. Roberts III
A. J. Spencer
R. W. Boyce, *Alternate*
S. Dasgupta, *Alternate*
P. D. Edwards, *Alternate*
R. E. Feigel, *Alternate*
S. M. Goodwin, *Alternate*
D. H. Hanrath, *Alternate*
K. A. Huber, *Alternate*
N. C. Kist, *Alternate*
A. A. Lotfi, *Alternate*
O. E. Trapp, *Staff Representative*

SUBCOMMITTEE ON DESIGN (SC-D)

D. P. Jones, *Chair*
F. S. Fitzgerald, *Secretary*
R. W. Barnes
C. Becht IV
O. F. Hedden
R. W. Mikitka
U. R. Miller
K. C. Morrison
W. J. O'Donnell
R. D. Schueler, Jr.
A. Selz

Subgroup on Design Analysis (SC-D)

T. P. Pastor, *Secretary*
M. R. Breach
P. J. Conlisk
A. G. Eggers
J. L. Hechmer
G. L. Hollinger
A. Kalnins
W. J. Koves
T. H. Liu
O. Maekawa
A. Merend
T. V. Narayanan
E. L. Thomas, Jr.
R. A. Whipple

Subgroup on Elevated Temperature Design (SC-D)

C. Becht IV, *Chair*
J. M. Corum, *Secretary*
C. R. Brinkman
R. D. Campbell
D. S. Griffin
R. I. Jetter
C. Lawton
W. J. O'Donnell
D. A. Osage
J. S. Porowski
C. C. Schultz, Jr.
L. K. Severud
D. F. Shaw
A. L. Snow
B. E. Thurgood

Subgroup on Fatigue Strength (SC-D)

C. R. Brinkman
P. R. Donavin
J. A. Hayward
J. L. Hechmer
D. P. Jones
G. Kharshafdjian
C. Lawton
A. Merend
H. H. Ziada

Subgroup on Openings (SC-D)

R. W. Mikitka, *Secretary*
M. R. Breach
V. T. Hwang
S. C. Lou
R. B. Luney
J. P. Madden
K. C. Morrison
D. R. Palmer
M. D. Rana
E. C. Rodabaugh

Special Working Group on Bolted Flanged Joints (SC-D)

R. W. Mikitka, *Chair*
G. D. Bibel
G. Kharshafdjian
D. L. Kurle
E. Michalopoulos
S. N. Pagay
J. R. Payne
R. W. Schneider
R. D. Schueler, Jr.
A. Selz

SUBCOMMITTEE ON SAFETY VALVE REQUIREMENTS (SC-SVR)

E. C. Kistner, Jr., *Chair*
M. D. Bernstein, *Vice Chair*
U. D'Urso, *Secretary*
J. F. Ball
J. A. Cox
R. D. Danzy
D. B. De Michael
R. J. Doelling
D. A. Douin
R. G. Friend
H. I. Gregg
S. F. Harrison, Jr.
C. F. Laitner
H. D. Michael
C. A. Neumann
D. K. Peetz
J. W. Reynolds
M. Robinson
D. J. Scallan
C. M. Schroepfer
A. J. Spencer
J. C. Standfast
E. A. Steen
J. A. West
T. J. Ferrigan, *Alternate*

Subgroup on Design (SC-SVR)

R. G. Friend, *Chair*
J. Cahoon, Jr.
R. D. Danzy
D. B. De Michael
R. J. Doelling
H. I. Gregg
S. R. Irvin, Sr.
C. F. Laitner
P. R. Sievert
A. J. Spencer
E. A. Steen
T. R. Tarbay
J. A. West

Subgroup on General Requirements (SC-SVR)

M. D. Bernstein, *Chair*
J. F. Ball
V. M. Deluca
D. A. Douin
H. D. Michael
C. A. Neumann
D. K. Peetz
J. W. Reynolds
J. W. Richardson
M. Robinson
J. C. Standfast

Subgroup on Testing (SC-SVR)

S. F. Harrison, Jr., *Chair*
S. Cammeresi
J. A. Cox
W. F. Hart
D. M. Papa
D. J. Scallan
C. M. Schroepfer
D. E. Snyder
B. S. York

PERSONNEL
Officers of ASTM Committee

(Cooperating in the Development of the Specifications Herein)

As of December 31, 1996

A1 COMMITTEE ON STEEL, STAINLESS STEEL, AND RELATED ALLOYS

A. S. Melilli, *Chair*
J. H. Martens, *Producer Vice Chair*
B. M. Dingman, *User Vice Chair*
W. Warke, *User Vice Chair*
J. H. Martens, *Producer Vice Chair*
E. Rau, *Membership Secretary*
D. Krouse, *Secretary*
A. J. Williams, *User Vice Chair*
E. R. Sullivan, *Staff Manager*
P. Speer, *Producer*
J. H. Martens, *Producer*
W. N. Holliday, *Producer*

A4 COMMITTEE ON IRON CASTINGS

R. S. Warrick, *Chair*
R. W. Bonds, *Vice Chair*
C. Armor, *Recording Secretary*
P. H. Meyst, *Membership Secretary*
B. Buckley, *Staff Manager*

PREFACE

The American Society of Mechanical Engineers (ASME) and the American Society for Testing and Materials (ASTM) have cooperated for more than fifty years in the preparation of material specifications adequate for safety in the field of pressure equipment for ferrous and nonferrous materials, contained in Section II (Part A — Ferrous and Part B — Nonferrous) of the ASME Boiler and Pressure Vessel Code.

The evolution of this cooperative effort is contained in Professor A. M. Greene's "History of the ASME Boiler Code," which was published as a series of articles in *Mechanical Engineering* from July 1952 through August 1953 and is now available from ASME in a special bound edition. The following quotations from this history, which was based upon the minutes of the ASME Boiler and Pressure Vessel Committee, will help focus on the cooperative nature of the specifications found in Section II, Material Specifications.

"*General discussion of material specifications comprising Paragraphs 1 to 112 of Part 2 and the advisability of having them agree with ASTM specifications," (1914).*

"*ASME Subcommittee appointed to confer with ASTM," (1916).*

"*Because of this cooperation the specifications of the 1918 Edition of the ASME Boiler Code were more nearly in agreement with ASTM specifications. In the 1924 Edition of the Code, 10 specifications were in complete agreement with ASTM specifications, 4 in substantial agreement and 2 covered materials for which ASTM had no corresponding specifications."*

"*In Section II, Material Specifications, the paragraphs were given new numbers beginning with S-1 and extending to S-213," (1925).*

"*Section II was brought into agreement with changes made in the latest ASTM specifications since 1921," (1932).*

"*The Subcommittee on Material Specifications arranged for the introduction of the revisions of many of the specifications so that they would agree with the latest form of the earlier ASTM specifications...," (1935).*

From the preceding, it is evident that many of the material specifications were prepared by the Boiler and Pressure Vessel Code Committees, then subsequently, by cooperative action, modified and identified as ASTM specifications. Section II, Parts A and B, currently contain many material specifications which are identical with the corresponding ASTM specifications and some which have been modified for Code usage.

In 1969, the American Welding Society began publication of specifications for welding rods, electrodes, and filler metals, hitherto issued by ASTM. The Boiler and Pressure Vessel Committee has recognized this new arrangement, and is now working with AWS on these specifications. Section II, Part C, contains the welding material specifications approved for Code use.

In 1992, the ASME Board of Pressure Technology Codes and Standards endorsed the use, of non-ASTM material for Boiler and Pressure Vessel Code applications. It is the intent to follow the procedures and practices currently in use to implement the adoption of non-ASTM materials.

All identical specifications are indicated by the ASME/originating organization symbols. The specifications prepared and copyrighted by ASTM, AWS, and other originating organizations are reproduced in the Code with the permission of the respective Society. The ASME Boiler and Pressure Vessel Committee has given careful consideration to each new and revised specification, and has made such changes as they deemed necessary to make the specification adaptable for Code usage. In addition, ASME has furnished ASTM with the basic requirements that should govern many proposed new specifications. Joint action will continue an effort to make the ASTM, AWS, and ASME specifications identical.

To assure that there will be a clear understanding on the part of the users of Section II, ASME publishes both the identical specifications and those amended for Code usage in three parts every three years, in the same page size to match the other sections of the Code, and Addenda are issued annually to provide the latest changes in Section II specifications.

The ASME Boiler and Pressure Vessel Code has been adopted into law by 48 states and many municipalities in the United States and by all of the Canadian Provinces.

Specifications
Listed by Materials

Steel Pipe

SA-53	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless	145
SA-106	Seamless Carbon Steel Pipe for High-Temperature Service	181
SA-134	Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)	197
SA-135	Electric-Resistance-Welded Steel Pipe	203
SA-312/SA-312M	Seamless and Welded Austenitic Stainless Steel Pipe	477
SA-333/SA-333M	Seamless and Welded Steel Pipe for Low-Temperature Service	517
SA-335/SA-335M	Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service	539
SA-358/SA-358M	Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service	603
SA-369/SA-369M	Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service	611
SA-376/SA-376M	Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service	685
SA-409/SA-409M	Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service	729
SA-426	Centrifugally Cast Ferritic Alloy Steel Pipe for High-Temperature Service	761
SA-430/SA-430M	Austenitic Steel Forged and Bored Pipe for High-Temperature Service	767
SA-451	Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service	809
SA-452	Centrifugally Cast Austenitic Steel Cold-Wrought Pipe for High-Temperature Service	815
SA-524	Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures	937
SA-530/SA-530M	General Requirements for Specialized Carbon and Alloy Steel Pipe	947
SA-587	Electric-Resistance-Welded Low-Carbon Steel Pipe for the Chemical Industry	1069
SA-660	Centrifugally Cast Carbon Steel Pipe for High-Temperature Service	1123
SA-671	Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures	1145
SA-672	Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures	1155
SA-691	Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures	1181
SA-727/SA-727M	Forgings, Carbon Steel, for Piping Components With Inherent Notch Toughness	1247
SA-731/SA-731M	Seamless, Welded Ferritic, and Martensitic Stainless Steel Pipe	1253
SA-790/SA-790M	Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe	1353
SA-813/SA-813M	Single- or Double-Welded Austenitic Stainless Steel Pipe	1377
SA-814/SA-814M	Cold-Worked Welded Austenitic Stainless Steel Pipe	1387

Steel Tubes

SA-178/SA-178M	Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes	213
SA-179/SA-179M	Seamless Cold-Drawn Low-Carbon Steel Heat Exchanger and Condenser Tubes	219
SA-192/SA-192M	Seamless Carbon Steel Boiler Tubes for High-Pressure Service	251
SA-199/SA-199M	Seamless Cold-Drawn Intermediate Alloy Steel Heat Exchanger and Condenser Tubes	285
SA-209/SA-209M	Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes	303
SA-210/SA-210M	Seamless Medium-Carbon Steel Boiler and Superheater Tubes	309
SA-213/SA-213M	Seamless Ferritic and Austenitic Alloy Steel Boiler, Superheater, and Heat Exchanger Tubes	315
SA-214/SA-214M	Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes	327

SA-226/SA-226M	Electric-Resistance-Welded Carbon Steel Boiler and Superheater Tubes for High Pressure Service	343
SA-249/SA-249M	Welded Austenitic Steel Boiler, Superheater, Heat Exchanger, and Condenser Tubes	371
SA-250/SA-250M	Electric-Resistance-Welded Ferritic Alloy Steel Boiler and Superheater Tubes	381
SA-268/SA-268M	Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service	423
SA-334/SA-334M	Seamless and Welded Carbon and Alloy Steel Tubes for Low-Temperature Service	529
SA-423/SA-423M	Seamless and Electric Welded Low-Alloy Steel Tubes	755
SA-450/SA-450M	General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes	795
SA-556/SA-556M	Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes	999
SA-557/SA-557M	Electric-Resistance-Welded Carbon Steel Feedwater Heater Tubes	1005
SA-688/SA-688M	Welded Austenitic Stainless Steel Feedwater Heater Tubes	1171
SA-789/SA-789M	Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service	1345
SA-803/SA-803M	Welded Ferritic Stainless Steel Feedwater Heater Tubes	1363

Steel Flanges, Fittings, Valves, and Parts

SA-105/SA-105M	Carbon Steel Forgings, for Piping Applications	171
SA-181/SA-181M	Carbon Steel Forgings, for General-Purpose Piping	223
SA-182/SA-182M	Forged or Rolled Alloy Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service	229
SA-216/SA-216M	Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service	329
SA-217/SA-217M	Steel Castings, Martensitic Stainless and Alloy, for Pressure Containing Parts Suitable for High-Temperature Service	333
SA-232	Chromium-Vanadium Alloy Steel Valve Spring Quality Wire	347
SA-234/SA-234M	Piping Fittings of Wrought Carbon Steel and Alloy for Moderate and Elevated Temperatures	353
SA-350/SA-350M	Forgings, Carbon and Low-Alloy Steel, Requiring Notch Toughness Testing for Piping Components	561
SA-351/SA-351M	Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts	573
SA-352/SA-352M	Steel Castings, Ferritic and Martensitic, for Pressure Containing Parts, Suitable for Low Temperature Service	579
SA-403/SA-403M	Wrought Austenitic Stainless Steel Piping Fittings	719
SA-420/SA-420M	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service	743
SA-522/SA-522M	Forged or Rolled 8 and 9% Nickel Alloy Steel Flanges, Fittings, Valves, and Parts for Low-Temperature Service	931
SA-592/SA-592M	High-Strength Quenched and Tempered Low-Alloy Steel Forged Fittings and Parts for Pressure Vessels	1077
SA-815/SA-815M	Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings	1397
SA-905	Steel Wire, Pressure Vessel Winding	1427

Steel Plates, Sheets, and Strip for Pressure Vessels

SA-20/SA-20M	General Requirements for Steel Plates for Pressure Vessels	57
SA-202/SA-202M	Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon	291
SA-203/SA-203M	Pressure Vessel Plates, Alloy Steel, Nickel	295
SA-204/SA-204M	Pressure Vessel Plates, Alloy Steel, Molybdenum	299
SA-225/SA-225M	Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium-Nickel	339
SA-240	Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels	363
SA-263	Corrosion-Resisting Chromium Steel Clad Plate, Sheet, and Strip	385
SA-264	Stainless Chromium-Nickel Steel Clad Plate, Sheet, and Strip	397
SA-265	Nickel and Nickel-Base Alloy Clad Steel Plate	409
SA-285/SA-285M	Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength	451
SA-299/SA-299M	Pressure Vessel Plates, Carbon Steel, Manganese-Silicon	455
SA-302/SA-302M	Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel	459
SA-353/SA-353M	Pressure Vessel Plates, Alloy Steel, 9 Percent Nickel, Double-Normalized and Tempered	587
SA-387/SA-387M	Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum	693

SA-414/SA-414M	Steel, Sheet, Carbon, for Pressure Vessels	739
SA-455/SA-455M	Pressure Vessel Plates, Carbon Steel, High-Strength Manganese	833
SA-480/SA-480M	General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip	855
SA-515/SA-515M	Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service	917
SA-516/SA-516M	Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service	923
SA-517/SA-517M	Pressure Vessel Plates, Alloy Steel, High Strength, Quenched and Tempered	927
SA-533/SA-533M	Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum and Manganese-Molybdenum-Nickel	957
SA-537/SA-537M	Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel	963
SA-542/SA-542M	Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Chromium-Molybdenum and Chromium-Molybdenum-Vanadium	991
SA-543/SA-543M	Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum	995
SA-553/SA-553M	Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, 8 and 9 Percent Nickel	999
SA-562/SA-562M	Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings	1021
SA-612/SA-612M	Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate- and Lower-Temperature Service	1097
SA-620/SA-620M	Steel Sheet, Carbon, Drawing Quality, Special Killed, Cold-Rolled	1103
SA-645/SA-645M	Pressure Vessel Plates, 5% Nickel Alloy Steel, Specially Heat Treated	1111
SA-662/SA-662M	Pressure Vessel Plates, Carbon-Manganese, for Moderate- and Lower-Temperature Service	1129
SA-666	Austenitic Stainless Steel, Sheet, Strip, Plate, and Flat Bar	1135
SA-693	Precipitation Hardening Stainless and Heat-Resisting Steel Plate, Sheet, and Strip	1189
SA-724/SA-724M	Pressure Vessel Plates, Carbon Steel, Quenched and Tempered, for Welded Layered Pressure Vessels	1243
SA-736/SA-736M	Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium and Nickel-Copper-Manganese-Molybdenum-Columbium Alloy Steel	1259
SA-737/SA-737M	Pressure Vessel Plates, High-Strength, Low-Alloy Steel	1265
SA-738/SA-738M	Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service	1269
SA-770/SA-770M	Through-Thickness Tension Testing of Steel Plates for Special Applications	1309
SA-812/SA-812M	Steel Sheet, High-Strength, Low-Alloy, Hot-Rolled, for Welded Layered Pressure Vessels	1373
SA-832/SA-832M	Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Vanadium	1407
SA-841/SA-841M	Steel Plates for Pressure Vessels, Produced by the Thermo-Mechanical Control Process (TMCP)	1421
SA/CSA-G40.21	Structural Quality Steels	1445
SA/EN 10028-2	Flat Products Made of Steels for Pressure Purposes	1447
SA/JIS G3118	Carbon Steel Plates for Pressure Vessels for Intermediate and Moderate Temperature Service	1449

Structural Steel

SA-6/SA-6M	General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use	1
SA-36/SA-36M	Carbon Structural Steel	129
SA-283/SA-283M	Low- and Intermediate-Tensile Strength Carbon Steel Plates	447

Steel Bars

SA-6/SA-6M	General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use	1
SA-29/SA-29M	General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished	103
SA-311/SA-311M	Steel Bars, Carbon, Stress-Relieved Cold-Drawn, Subject to Mechanical Property Requirements	471

SA-479/SA-479M	Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels	843
SA-484/SA-484M	General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings	881
SA-564/SA-564M	Hot-Rolled and Cold-Finished Age-Hardening Stainless and Heat-Resisting Steel Bars and Shapes	1039
SA-638/SA-638M	Precipitation Hardening Iron Base Superalloy Bars, Forgings, and Forging Stock for High-Temperature Service	1107
SA-675	Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties	1165
SA-695	Steel Bars, Carbon, Hot-Wrought, Special Quality, for Fluid Power Applications	1199
SA-696	Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components	1203
SA-739	Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both	1275

Steel Bolting Materials

SA-193/SA-193M	Alloy Steel and Stainless Steel Bolting Materials for High-Temperature Service	255
SA-194/SA-194M	Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service	271
SA-307	Carbon Steel Bolts and Studs, 60 000 Psi Tensile Strength	463
SA-320/SA-320M	Alloy Steel Bolting Materials for Low-Temperature Service	491
SA-325	Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength	505
SA-354	Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners	593
SA-437/SA-437M	Alloy Steel Turbine-Type Bolting Material Specially Heat Treated for High-Temperature Service	779
SA-449	Quenched and Tempered Steel Bolts and Studs	787
SA-453/SA-453M	Bolting Materials, High Temperature, 50 to 120 ksi [345 to 827 MPa] Yield Strength, With Expansion Coefficients Comparable to Austenitic Steel	821
SA-540/SA-540M	Alloy Steel Bolting Materials for Special Applications	969
SA-563	Carbon and Alloy Steel Nuts	1025
SA-574	Alloy Steel Socket-Head Screws	1049
SF-568	Carbon and Alloy Steel Externally Threaded Metric Fasteners	1433

Steel Billets and Forgings

SA-105/SA-105M	Carbon Steel Forgings, for Piping Applications	171
SA-181/SA-181M	Carbon Steel Forgings, for General-Purpose Piping	223
SA-266/SA-266M	Carbon Steel Forgings, for Pressure Vessel Components	417
SA-336/SA-336M	Alloy Steel Forgings for Pressure and High-Temperature Parts	551
SA-350/SA-350M	Forgings, Carbon and Low-Alloy Steel, Requiring Notch Toughness Testing for Piping Components	561
SA-372/SA-372M	Carbon and Alloy Steel Forgings for Thin-Walled Pressure Vessels	677
SA-484/SA-484M	General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings	881
SA-508/SA-508M	Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings for Pressure Vessels	907
SA-541/SA-541M	Quenched and Tempered Carbon and Alloy Steel Forgings for Pressure Vessel Components	983
SA-638/SA-638M	Precipitation Hardening Iron Base Superalloy Bars, Forgings, and Forging Stock for High-Temperature Service	1107
SA-649/SA-649M	Forged Steel Rolls Used for Corrugating Paper Machinery	1117
SA-705/SA-705M	Age-Hardening Stainless and Heat-Resisting Steel Forgings	1227
SA-723/SA-723M	Alloy Steel Forgings for High-Strength Pressure Component Application	1237
SA-745/SA-745M	Ultrasonic Examination of Austenitic Steel Forgings	1279
SA-765/SA-765M	Carbon Steel and Low-Alloy Steel Pressure Vessel Component Forgings With Mandatory Toughness Requirements	1301
SA-788	Steel Forgings, General Requirements	1333
SA-836/SA-836M	Forgings, Titanium-Stabilized Carbon Steel, for Glass-Lined Piping and Pressure Vessel Service	1415

Steel Castings

SA-216/SA-216M Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service 329
SA-217/SA-217M Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts Suitable for High-Temperature Service 333
SA-351/SA-351M Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts 573
SA-352/SA-352M Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low Temperature Service 579
SA-487/SA-487M Steel Castings Suitable for Pressure Service 897
SA-494/SA-494M Castings, Nickel and Nickel Alloy 905
SA-609 Castings, Carbon, Low Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof 1083
SA-667/SA-667M Centrifugally Cast Dual Metal (Gray and White Cast Iron) Cylinders 1143
SA-703/SA-703M Steel Castings, General Requirements, for Pressure-Containing Parts 1207
SA-747/SA-747M Precipitation Hardening Stainless Steel Castings 1287
SA-781/SA-781M Castings, Steel and Alloy, Common Requirements, for General Industrial Use 1317

Corrosion-Resisting and Heat-Resisting Steels

SA-182/SA-182M Forged or Rolled Alloy Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service 229
SA-193/SA-193M Alloy Steel and Stainless Steel Bolting Materials for High-Temperature Service 255
SA-194/SA-194M Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service 271
SA-213/SA-213M Seamless Ferritic and Austenitic Alloy Steel Boiler, Superheater, and Heat Exchanger Tubes 315
SA-216/SA-216M Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service 329
SA-217/SA-217M Steel Castings, Martensitic Stainless and Alloy, for Pressure Containing Parts Suitable for High-Temperature Service 333
SA-240 Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels 363
SA-249/SA-249M Welded Austenitic Steel Boiler, Superheater, Heat Exchanger, and Condenser Tubes 371
SA-263 Corrosion-Resisting Chromium Steel Clad Plate, Sheet, and Strip 385
SA-264 Stainless Chromium-Nickel Steel Clad Plate, Sheet, and Strip 397
SA-265 Nickel and Nickel-Base Alloy Clad Steel Plate 409
SA-268/SA-268M Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service 423
SA-312/SA-312M Seamless and Welded Austenitic Stainless Steel Pipe 477
SA-320/SA-320M Alloy Steel Bolting Materials for Low-Temperature Service 491
SA-336/SA-336M Alloy Steel Forgings for Pressure and High-Temperature Parts 551
SA-351/SA-351M Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts 573
SA-358/SA-358M Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service 603
SA-369/SA-369M Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service 611
SA-376/SA-376M Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service 685
SA-403/SA-403M Wrought Austenitic Stainless Steel Piping Fittings 719
SA-409/SA-409M Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service 729
SA-426 Centrifugally Cast Ferritic Alloy Steel Pipe for High-Temperature Service 761
SA-430/SA-430M Austenitic Steel Forged and Bored Pipe for High-Temperature Service 767
SA-437/SA-437M Alloy Steel Turbine-Type Bolting Material Specially Heat Treated for High-Temperature Service 779
SA-451 Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service 809
SA-452 Centrifugally Cast Austenitic Steel Cold-Wrought Pipe for High-Temperature Service 815
SA-479/SA-479M Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels 843
SA-484/SA-484M General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings 881
SA-515/SA-515M Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service 917
SA-564/SA-564M Hot-Rolled and Cold-Finished Age-Hardening Stainless and Heat-Resisting Steel Bars and Shapes 1039

SA-638/SA-638M Precipitation Hardening Iron Base Superalloy Bars, Forgings, and Forging Stock for High-Temperature Service ... 1107
SA-660 Centrifugally Cast Carbon Steel Pipe for High-Temperature Service ... 1123
SA-666 Austenitic Stainless Steel, Sheet, Strip, Plate and Flat Bar ... 1135
SA-691 Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures ... 1181
SA-705/SA-705M Age-Hardening Stainless and Heat-Resisting Steel Forgings ... 1227
SA-789/SA-789M Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service ... 1345
SA-790/SA-790M Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe ... 1353
SA-814/SA-814M Cold-Worked Welded Austenitic Stainless Steel Pipe ... 1387
SA-815/SA-815M Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings ... 1397

Wrought Iron, Cast Iron, and Malleable Iron

SA-47 Ferritic Malleable Iron Castings ... 137
SA-278 Gray Iron Castings for Pressure Containing Parts for Temperatures Up to 650°F ... 441
SA-395 Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures ... 707
SA-476 Ductile Iron Castings for Paper Mill Dryer Rolls ... 837
SA-748/SA-748M Statically Cast Chilled White Iron-Gray Iron Dual Metal Rolls for Pressure Vessel Use 1293
SA-834 Common Requirements for Iron Castings for General Industrial Use ... 1411

Methods

SA-275/SA-275M Magnetic Particle Examination of Steel Forgings ... 431
SA-370 Standard Test Methods and Definitions for Mechanical Testing of Steel Products ... 617
SA-388/SA-388M Ultrasonic Examination of Heavy Steel Forgings ... 699
SA-435/SA-435M Straight-Beam Ultrasonic Examination of Steel Plates ... 775
SA-577/SA-577M Ultrasonic Angle-Beam Examination of Steel Plates ... 1059
SA-578/SA-578M Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications ... 1063
SA-745/SA-745M Ultrasonic Examination of Austenitic Steel Forgings ... 1279
SA-751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products ... 1295

Specifications
Listed in Numeric Sequence

SA-6/SA-6M	General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use	1
SA-20/SA-20M	General Requirements for Steel Plates for Pressure Vessels	57
SA-29/SA-29M	General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished	103
SA-36/SA-36M	Carbon Structural Steel	129
SA-47	Ferritic Malleable Iron Castings	137
SA-53	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless	145
SA-105/SA-105M	Carbon Steel Forgings, for Piping Applications	171
SA-106	Seamless Carbon Steel Pipe for High-Temperature Service	181
SA-134	Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)	197
SA-135	Electric-Resistance-Welded Steel Pipe	203
SA-178/SA-178M	Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes	213
SA-179/SA-179M	Seamless Cold-Drawn Low-Carbon Steel Heat Exchanger and Condenser Tubes	219
SA-181/SA-181M	Carbon Steel Forgings, for General-Purpose Piping	223
SA-182/SA-182M	Forged or Rolled Alloy Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service	229
SA-192/SA-192M	Seamless Carbon Steel Boiler Tubes for High-Pressure Service	251
SA-193/SA-193M	Alloy Steel and Stainless Steel Bolting Materials for High-Temperature Service	255
SA-194/SA-194M	Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service	271
SA-199/SA-199M	Seamless Cold-Drawn Intermediate Alloy Steel Heat Exchanger and Condenser Tubes	285
SA-202/SA-202M	Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon	291
SA-203/SA-203M	Pressure Vessel Plates, Alloy Steel, Nickel	295
SA-204/SA-204M	Pressure Vessel Plates, Alloy Steel, Molybdenum	299
SA-209/SA-209M	Seamless Carbon-Molybdenum Alloy Steel Boiler and Superheater Tubes	303
SA-210/SA-210M	Seamless Medium-Carbon Steel Boiler and Superheater Tubes	309
SA-213/SA-213M	Seamless Ferritic and Austenitic Alloy Steel Boiler, Superheater, and Heat Exchanger Tubes	315
SA-214/SA-214M	Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes	327
SA-216/SA-216M	Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service	329
SA-217/SA-217M	Steel Castings, Martensitic Stainless and Alloy, for Pressure Containing Parts Suitable for High-Temperature Service	333
SA-225/SA-225M	Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium-Nickel	339
SA-226/SA-226M	Electric-Resistance-Welded Carbon Steel Boiler and Superheater Tubes for High-Pressure Service	343
SA-232/SA-232M	Chromium-Vanadium Alloy Steel Valve Spring Quality Wire	347
SA-234/SA-234M	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures	353
SA-240	Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels	363
SA-249/SA-249M	Welded Austenitic Steel Boiler, Superheater, Heat Exchanger, and Condenser Tubes	371
SA-250/SA-250M	Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes	381

SA-263	Corrosion-Resisting Chromium Steel Clad Plate, Sheet, and Strip	385
SA-264	Stainless Chromium-Nickel Steel Clad Plate, Sheet, and Strip	397
SA-265	Nickel and Nickel-Base Alloy Clad Steel Plate	409
SA-266/SA-266M	Carbon Steel Forgings, for Pressure Vessel Components	417
SA-268/SA-268M	Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service	423
SA-275/SA-275M	Magnetic Particle Examination of Steel Forgings	431
SA-278	Gray Iron Castings for Pressure Containing Parts for Temperature Up to 650°F	441
SA-283/SA-283M	Low- and Intermediate-Tensile Strength Carbon Steel Plates	447
SA-285/SA-285M	Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength	451
SA-299/SA-299M	Pressure Vessel Plates, Carbon Steel, Manganese-Silicon	455
SA-302/SA-302M	Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel	459
SA-307	Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength	463
SA-311/SA-311M	Steel Bars, Carbon, Stress-Relieved Cold-Drawn, Subject to Mechanical Property Requirements	471
SA-312/SA-312M	Seamless and Welded Austenitic Stainless Steel Pipe	477
SA-320/SA-320M	Alloy Steel Bolting Materials for Low-Temperature Service	491
SA-325	Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength	505
SA-333/SA-333M	Seamless and Welded Steel Pipe for Low-Temperature Service	517
SA-334/SA-334M	Seamless and Welded Carbon and Alloy Steel Tubes for Low-Temperature Service	529
SA-335/SA-335M	Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service	539
SA-336/SA-336M	Alloy Steel Forgings for Pressure and High-Temperature Parts	551
SA-350/SA-350M	Forgings, Carbon and Low-Alloy Steel, Requiring Notch Toughness Testing for Piping Components	561
SA-351/SA-351M	Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts	573
SA-352/SA-352M	Steel Castings, Ferritic and Martensitic, for Pressure Containing Parts, Suitable for Low Temperature Service	579
SA-353/SA-353M	Pressure Vessel Plates, Alloy Steel, 9 Percent Nickel, Double-Normalized and Tempered	587
SA-354	Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners	593
SA-358/SA-358M	Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service	603
SA-369/SA-369M	Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service	611
SA-370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products	617
SA-372/SA-372M	Carbon and Alloy Steel Forgings for Thin-Walled Pressure Vessels	677
SA-376/SA-376M	Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service	685
SA-387/SA-387M	Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum	693
SA-388/SA-388M	Ultrasonic Examination of Heavy Steel Forgings	699
SA-395	Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures	707
SA-403/SA-403M	Wrought Austenitic Stainless Steel Piping Fittings	719
SA-409/SA-409M	Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service	729
SA-414/SA-414M	Steel, Sheet, Carbon, for Pressure Vessels	739
SA-420/SA-420M	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service	743
SA-423/SA-423M	Seamless and Electric-Welded Low-Alloy Steel Tubes	755
SA-426	Centrifugally Cast Ferritic Alloy Steel Pipe for High-Temperature Service	761
SA-430/SA-430M	Austenitic Steel Forged and Bored Pipe for High-Temperature Service	767
SA-435/SA-435M	Straight-Beam Ultrasonic Examination of Steel Plates	775
SA-437/SA-437M	Alloy Steel Turbine-Type Bolting Material Specially Heat Treated for High-Temperature Service	779
SA-449	Quenched and Tempered Steel Bolts and Studs	787
SA-450/SA-450M	General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes	795
SA-451	Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service	809
SA-452	Centrifugally Cast Austenitic Steel Cold-Wrought Pipe for High-Temperature Service	815

SA-453/SA-453M	Bolting Materials, High Temperature, 50 to 120 ksi [345 to 827 MPa] Yield Strength, With Expansion Coefficients Comparable to Austenitic Steel	821
SA-455/SA-455M	Pressure Vessel Plates, Carbon Steel, High-Strength Manganese	833
SA-476	Ductile Iron Castings for Paper Mill Dryer Rolls	837
SA-479/SA-479M	Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels	843
SA-480/SA-480M	General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip	855
SA-484/SA-484M	General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings	881
SA-487/SA-487M	Steel Castings Suitable for Pressure Service	897
SA-494/SA-494M	Castings, Nickel and Nickel Alloy	905
SA-508/SA-508M	Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings for Pressure Vessels	907
SA-515/SA-515M	Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service	917
SA-516/SA-516M	Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service	923
SA-517/SA-517M	Pressure Vessel Plates, Alloy Steel, High Strength, Quenched and Tempered	927
SA-522/SA-522M	Forged or Rolled 8 and 9% Nickel Alloy Steel Flanges, Fittings, Valves, and Parts for Low-Temperature Service	931
SA-524	Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures	937
SA-530/SA-530M	General Requirements for Specialized Carbon and Alloy Steel Pipe	947
SA-533/SA-533M	Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum and Manganese-Molybdenum-Nickel	957
SA-537/SA-537M	Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel	963
SA-540/SA-540M	Alloy Steel Bolting Materials for Special Applications	969
SA-541/SA-541M	Quenched and Tempered Carbon and Alloy Steel Forgings for Pressure Vessel Components	983
SA-542/SA-542M	Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Chromium-Molybdenum and Chromium-Molybdenum-Vanadium	991
SA-543/SA-543M	Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum	995
SA-553/SA-553M	Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9 Percent Nickel	999
SA-556/SA-556M	Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes	1005
SA-557/SA-557M	Electric-Resistance-Welded Carbon Steel Feedwater Heater Tubes	1013
SA-562/SA-562M	Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings	1021
SA-563	Carbon and Alloy Steel Nuts	1025
SA-564/SA-564M	Hot-Rolled and Cold-Finished Age-Hardening Stainless and Heat-Resisting Steel Bars and Shapes	1039
SA-574	Alloy Steel Socket-Head Screws	1049
SA-577/SA-577M	Ultrasonic Angle-Beam Examination of Steel Plates	1059
SA-578/SA-578M	Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications	1063
SA-587	Electric-Resistance-Welded Low-Carbon Steel Pipe for the Chemical Industry	1069
SA-592/SA-592M	High-Strength Quenched and Tempered Low-Alloy Steel Forged Fittings and Parts for Pressure Vessels	1077
SA-609	Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof	1083
SA-612/SA-612M	Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate- and Lower-Temperature Service	1097
SA-620/SA-620M	Steel Sheet, Carbon, Drawing Quality, Special Killed, Cold-Rolled	1103
SA-638/SA-638M	Precipitation Hardening Iron Base Superalloy Bars, Forgings, and Forging Stock for High-Temperature Service	1107
SA-645/SA-645M	Pressure Vessel Plates, 5% Nickel Alloy Steel, Specially Heat Treated	1111
SA-649/SA-649M	Forged Steel Rolls Used for Corrugating Paper Machinery	1117
SA-660	Centrifugally Cast Carbon Steel Pipe for High-Temperature Service	1123
SA-662/SA-662M	Pressure Vessel Plates, Carbon-Manganese, for Moderate- and Lower-Temperature Service	1129

SA-666	Austenitic Stainless Steel, Sheet, Strip, Plate, and Flat Bar	1135
SA-667/SA-667M	Centrifugally Cast Dual Metal (Gray and White Cast Iron) Cylinders	1143
SA-671	Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures	1145
SA-672	Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures	1155
SA-675/SA-675M	Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties	1165
SA-688/SA-688M	Welded Austenitic Stainless Steel Feedwater Heater Tubes	1171
SA-691	Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures	1181
SA-693	Precipitation Hardening Stainless and Heat-Resisting Steel Plate, Sheet, and Strip	1189
SA-695	Steel Bars, Carbon, Hot-Wrought, Special Quality, for Fluid Power Applications	1199
SA-696	Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components	1203
SA-703/SA-703M	Steel Castings, General Requirements, for Pressure-Containing Parts	1207
SA-705/SA-705M	Age-Hardening Stainless and Heat-Resisting Steel Forgings	1227
SA-723/SA-723M	Alloy Steel Forgings for High-Strength Pressure Component Application	1237
SA-724/SA-724M	Pressure Vessel Plates, Carbon Steel, Quenched and Tempered, for Welded Layered Pressure Vessels	1243
SA-727/SA-727M	Forgings, Carbon Steel, for Piping Components With Inherent Notch Toughness	1247
SA-731/SA-731M	Seamless, Welded Ferritic, and Martensitic Stainless Steel Pipe	1253
SA-736/SA-736M	Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium and Nickel-Copper-Manganese-Molybdenum-Columbium Alloy Steel	1259
SA-737/SA-737M	Pressure Vessel Plates, High-Strength, Low-Alloy Steel	1265
SA-738/SA-738M	Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service	1269
SA-739	Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both	1275
SA-745/SA-745M	Ultrasonic Examination of Austenitic Steel Forgings	1279
SA-747/SA-747M	Precipitation Hardening Stainless Steel Castings	1287
SA-748/SA-748M	Statically Cast Chilled White Iron-Gray Iron Dual Metal Rolls for Pressure Vessel Use	1293
SA-751	Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products	1295
SA-765/SA-765M	Carbon Steel and Low-Alloy Steel Pressure Vessel Component Forgings With Mandatory Toughness Requirements	1301
SA-770/SA-770M	Through-Thickness Tension Testing of Steel Plates for Special Applications	1309
SA-781/SA-781M	Castings, Steel and Alloy, Common Requirements, for General Industrial Use	1317
SA-788	Steel Forgings, General Requirements	1333
SA-789/SA-789M	Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service	1345
SA-790/SA-790M	Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe	1353
SA-803/SA-803M	Welded Ferritic Stainless Steel Feedwater Heater Tubes	1363
SA-812/SA-812M	Steel Sheet, High-Strength, Low-Alloy, Hot-Rolled, for Welded Layered Pressure Vessels	1373
SA-813/SA-813M	Single- or Double-Welded Austenitic Stainless Steel Pipe	1377
SA-814/SA-814M	Cold-Worked Welded Austenitic Stainless Steel Pipe	1387
SA-815/SA-815M	Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings	1397
SA-832/SA-832M	Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Vanadium	1407
SA-834	Common Requirements for Iron Castings for General Industrial Use	1411
SA-836/SA-836M	Forgings, Titanium-Stabilized Carbon Steel, for Glass-Lined Piping and Pressure Vessel Service	1415
SA-841/SA-841M	Steel Plates for Pressure Vessels, Produced by the Thermo-Mechanical Control Process (TMCP)	1421
SA-905	Steel Wire, Pressure Vessel Winding	1427
SF-568	Carbon and Alloy Steel Externally Threaded Metric Fasteners	1433
SA/CSA-G40.21	Structural Quality Steels	1445
SA/EN 10028-2	Flat Products Made of Steels for Pressure Purposes	1447
SA/JIS G3118	Carbon Steel Plates for Pressure Vessels for Intermediate and Moderate Temperature Service	1449

APPENDIX 1 — MANDATORY PREPARATION OF TECHNICAL INQUIRIES TO THE BOILER AND PRESSURE VESSEL COMMITTEE

1-100 INTRODUCTION

The ASME Boiler and Pressure Vessel Committee meets regularly to consider written requests for interpretations and revisions to the Code rules, and to develop new rules as dictated by technological development. The Committee's activities in this regard are limited strictly to interpretations of the rules or to the consideration of revisions to the present rules on the basis of new data or technology. As a matter of published policy, ASME does not approve, certify, rate, or endorse any item, construction, proprietary device, or activity, and, accordingly, inquiries requiring such consideration will be returned. Moreover, ASME does not act as a consultant on specific engineering problems or on the general application or understanding of the Code rules. If, based on the inquiry information submitted, it is the opinion of the Committee that the inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

All inquiries that do not provide the information needed for the Committee's full understanding will be returned.

1-200 INQUIRY FORMAT

Inquiries shall be limited strictly to interpretations of the rules or to the consideration of revisions to the present rules on the basis of new data or technology. Inquiries shall be submitted in the following format.

(a) Scope. Involve a single rule or closely related rules. An inquiry letter concerning unrelated subjects will be returned.

(b) Background. State the purpose of the inquiry, which would be either to obtain an interpretation of Code rules, or to propose consideration of a revision to the present rules. Provide concisely the information needed for the Committee's understanding of the inquiry, being sure to include reference to the applicable Code Section, Division, Edition, Addenda, paragraphs, figures, and tables. If sketches are provided, they shall be limited to the scope of the inquiry.

(c) Inquiry Structure. Prepare statements in a condensed and precise question format, omitting superfluous background information, and, where appropriate, composed in such a way that "yes" or "no" (perhaps with provisos) would be an acceptable reply. This inquiry statement should be technically and editorially correct.

(d) Proposed Reply. State what it is believed that the Code requires. If in the inquirer's opinion a revision to the Code is needed, recommended wording shall be provided.

1-300 SUBMITTAL

Inquiries shall preferably be submitted in typewritten form; however, legible handwritten inquiries will also be considered. They shall include the name and mailing address of the inquirer, and be mailed to the following address:

Secretary
ASME Boiler and Pressure Vessel Committee
Three Park Avenue
New York, NY 10016-5990

APPENDIX A — NONMANDATORY ACCEPTABLE ASTM EDITIONS

All materials allowed by the various Code Sections and used for construction within the scope of their rules shall be furnished in accordance with the Material Specifications contained within Section II and this Appendix except where otherwise provided in Code Cases or in the applicable Section of the Code. Materials covered by these Specifications are acceptable for use in items covered by the Code Sections only to the degree indicated in the applicable Section. Materials for Code use should preferably be ordered, produced, and documented on this basis; however, material produced under an ASTM Specification may be used in lieu of the corresponding ASME Specification as listed in this Appendix. Material produced to an ASME or ASTM Specification with requirements different from the requirements of the corresponding Specification may also be used in accordance with the above, provided the material manufacturer or vessel manufacturer certifies with evidence acceptable to the Authorized Inspector that the corresponding Specification requirements have been met. This Appendix lists the Specifications and acceptable dates of issue as well as the Book sections of the ASME Boiler Code in which the specification is approved for use.

	Book Section								
Specification	I	III	IV	VIII-I	VIII-2	Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
SA-6/SA-6M Identical except for deletion of Annex A2	-General Requirements, Rolled Products					×	. . .	93b	88c thru 93b
SA-20/SA-20M Identical	-General Requirements, Plates			×	×	. . .	×	96a[e1]	88 thru 96a[e1]
SA-29/SA-29M Identical	-General Requirements, Bars					. . .	×	93a	88 thru 93a
SA-36/SA-36M Identical	×	×	×	×	×	×	×	96	88 thru 96
SA-47 Identical	. . .	. . .	. . .	×	. . .	. . .	. . .	90	84 thru 90
SA-53 Identical	×	×	×	×	. . .	. . .	×	96	88a thru 96

Specification	Book Section I	III	IV	VIII-1	VIII-2	Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
SA-105/SA-105M	×	×	×	×	×	×	×	96	87a thru 96
Identical									
SA-106	×	×	×	×	×	×	×	95	88a thru 95
Identical except for editorial differences in 8.1, 13.4, and 24.1 and deletion of ASTM caveat 1.5									
SA-134	...	...	×	...	...	...	...	93	85 thru 93
Identical except for additional requirement as shown in spec									
SA-135	...	...	×	×	...	...	...	96	88 thru 96
Identical									
SA-178/SA-178M	×	×	×	×	×	×	×	95	89 thru 95
Identical									
SA-179/SA-179M	...	...	...	×	...	...	...	90a	88a thru 90a
Identical									
SA-181/SA-181M	×	×	×	×	×	×	×	95b	87 thru 95b
Identical except for editorial differences in 7.3.2 and 12.6									
SA-182/SA-182M	×	×	...	×	×	×	×	95c	87a thru 95c
Identical except for the clarified heat treatment requirements by the addition of Note 4 to Table 1									
SA-192/SA-192M	×	...	×	×	...	...	...	91	88 thru 91
Identical									
SA-193/SA-193M	...	×	×	×	×	×	×	95	87 thru 95
Identical except for differences in 3.1.1									
SA-194/SA-194M	...	×	...	...	×	×	...	95a	87 thru 95a
Identical except for editorial differences in 4.1.1 and S5.1									
SA-199/SA-199M	...	...	...	×	×	...	...	92	88 thru 92
Identical									
SA-202/SA-202M	×	...	...	×	...	...	...	93	82 thru 93
Identical									
SA-203/SA-203M	×	×	...	×	×	...	...	93	82 thru 93
Identical									
SA-204/SA-204M	×	×	...	×	×	×	...	93	88 thru 93
Identical									
SA-209/SA-209M	×	...	...	×	×	...	...	95	88 thru 95
Identical									
SA-210/SA-210M	×	×	×	×	×	×	×	95	88 thru 95
Identical except for editorial differences in Table 3									
SA-213/SA-213M	×	×	×	×	×	×	×	95a	88a thru 95a
Identical except for editorial differences in 6.1 and 6.1.1 and the deletion of S3, and clarified heat treatment requirements in 6.4									
SA-214/SA-214M	...	...	...	×	...	...	...	90a	88 thru 90a
Identical									

Specification	Book Section I	III	IV	VIII-1	VIII-2	Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
SA-216/SA-216M	×	×	×	×	×	×	×	93	84b thru 93
Identical except for addition of 2.3 and editorial differences in 2.1 and 10.1									
SA-217/SA-217M	×	×	...	×	×	×	×	93	93 thru 93
Identical except for editorial changes in 2.2, 9.1, and 9.3									
SA-225/SA-225M	...	...	...	×	×	...	...	93	86 thru 93
Identical									
SA-226/SA-226M	×	...	×	×	...	...	...	95	88 thru 95
Identical									
SA-232	...	...	...	...	...	...	...	91	...
Identical									
SA-234/SA-234M	×	×	...	×	×	×	×	95a	82a thru 95a
Identical									
SA-240	×	×	×	×	×	×	×	95a	88c thru 97a **A99**
Identical except for editorial differences in Table 1									
SA-249/SA-249M	×	×	×	×	×	×	×	96a	88b thru 96a
Identical except for the deletion of S5, which addresses unstraightened tubes, and clarified heat treatment requirements in 6.2									
SA-250/SA-250M	×	...	...	×	...	...	×	95	88a thru 95
Identical									
SA-263	...	...	...	...	...	...	...	94a	88 thru 94a
Identical									
SA-264	...	...	...	...	...	...	...	94a	88 thru 94a
Identical									
SA-265	...	...	...	...	...	...	...	94a	88 thru 94a
Identical									
SA-266/SA-266M	×	×	×	×	×	×	×	95	87 thru 95
Identical									
SA-268/SA-268M	×	×	...	×	×	...	×	94	88b thru 94
Identical									
SA-275/SA-275M	- Magnetic Particle Examination of Forgings						...	96	86 thru 96
Identical except for editorial differences in 15.1									
SA-278	...	...	...	×	...	...	×	93	85 thru 93
Identical									
SA-283/SA-283M	...	×	...	×	×	×	...	93	88 thru 93
Identical									
SA-285/SA-285M	×	×	×	×	×	...	×	90	82(1987) thru 90
Identical									
SA-299/SA-299M	×	×	...	×	×	×	...	90	82(1987) thru 90
Identical									

Specification	Book Section I	III	IV	VIII-1	VIII-2	Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
SA-302/SA-302M	×	×	...	×	×	×	×	93	82 thru 93
Identical									
SA-307	...	×	×	×	...	×	...	93a	84 thru 93a
Identical									
SA-311/SA-311M	...	...	×	...	...	...	×	90b	...
Identical except for deletion of 5.1.11 and editorial correction to Table 1									
SA-312/SA-312M	×	×	...	×	×	×	×	95a	88a thru 95a
Identical except for clarified heat treatment requirements in 5.2.2									
SA-320/SA-320M	...	×	×	×	×	×	...	94a(R95)[e1]	85 thru 94a(R95)[e1]
Identical									
SA-325	...	×	×	×	...	×	...	94	86a thru 94
Identical except for editorial differences in para. 4.3.4									
SA-333/SA-333M	...	×	...	×	×	...	×	94	...
Identical									
SA-334/SA-334M	...	×	...	×	×	...	...	96	88[e1] thru 96
Identical									
SA-335/SA-335M	×	×	...	×	×	×	×	95a	88a thru 95a
Identical									
SA-336/SA-336M	×	×	...	×	×	×	×	96	87a thru 96
Identical except for clarified heat treatment requirements in 6.2									
SA-350/SA-350M	...	×	...	×	×	...	×	95b	87 thru 95b
Identical									
SA-351/SA-351M	×	×	×	×	×	×	×	94a	86 thru 94a
Identical except for editorial differences in 10.1									
SA-352/SA-352M	...	×	...	×	×	...	×	93[e1]	88 thru 93[e1]
Identical except for 2.3, 2.9 and deletion of the Appendix									
SA-353/SA-353M	...	×	...	×	×	...	×	93[e1]	87 thru 93[e1]
Identical									
SA-354	...	×	×	×	...	×	...	95	86 thru 95
Identical									
SA-358/SA-358M	...	×	...	×	...	×	×	95a	88 thru 95a
Identical except for clarified heat treatment requirements in 5.3.1, editorial differences in Table 1, and the following additional requirements									
SA-369/SA-369M	×	×	...	×	×	×	×	92	88 thru 92
Identical									
SA-370	- Mechanical Testing of Steel Products					×	×	96	77 thru 96
Identical									

Specification	Book Section I	III	IV	VIII-1	VIII-2	Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions	
SA-372/SA-372M	...	×	...	×	×	...	×	95	95	**A99**
Identical except for the additional requirements in 5.3										
SA-376/SA-376M	×	×	...	×	×	×	×	93	88 thru 93	
Identical except for editorial differences in Table 2, and clarified heat treatment requirements in 5.3.1										
SA-387/SA-387M	×	×	...	×	×	×	×	92[e1]	88 thru 92[e1]	
Identical										
SA-388/SA-388M	- Ultrasonic Testing of Forgings						×	94	86 thru 94	
Identical										
SA-395	...	...	...	×	...	×	×	88(R93)[e1]	80 thru 88(1993)[e1]	
Identical										
SA-403/SA-403M	...	×	...	×	×	×	×	95	86 thru 95	
Identical except for clarified heat treatment requirements in 6.1										
SA-409/SA-409M	...	×	...	×	...	...	×	95a	88 thru 95a	
Identical except for clarified heat treatment requirements in 5.3.1 and the addition of the following additional requirements										
SA-414/SA-414M	...	×	×	×	...	...	×	92(1993)[e1]	88 thru 92(1993)[e1]	**A99**
Identical except for clarification of deoxidation practice in 5.3 and Tables 1 and 2										
SA-420/SA-420M	...	×	...	×	×	...	...	95	85a thru 95	
Identical										
SA-423/SA-423M	×	...	...	×	×	...	...	95	89 thru 95	
Identical										
SA-426	...	×	...	...	...	×	...	92	80 thru 92	
Identical										
SA-430/SA-430M	×	×	...	×	×	×	×	91	88[e1] thru 91	
Identical except for clarified heat treatment requirements in 5.5.1										
SA-435/SA-435M	- Straight Beam Ultrasonic of Plates					...	...	90	82(1987) thru 90	
Identical										
SA-437/SA-437M	...	×	...	...	...	...	...	94	84b thru 94	
Identical										
SA-449	...	×	...	×	...	×	...	92b	87 thru 92b	
Identical except for editorial differences in 5.1.4										
SA-450/SA-450M	- General Requirements for Tubes					...	×	96	88a thru 96	
Identical										
SA-451	...	×	...	...	...	...	...	93	80(1985) thru 93	
Identical except for editorial differences in 12.1										
SA-452	...	×	...	×	...	×	...	88	...	
Identical										

Specification	Book Section I	III	IV	VIII-1	VIII-2	Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
SA-453/SA-453M Identical	...	×	...	×	...	×	...	94	86 thru 94
SA-455/SA-455M Identical	...	×	×	×	...	...	×	90	82(1987) thru 90
SA-476 Identical	...	...	...	×	...	...	...	90	82 thru 90
SA-479/SA-479 Identical except for a new para. 5.1.2 clarifying the heat treatment requirements and editorial differences in Table 2	×	×	×	×	×	×	×	95b	87b thru 95b
SA-480/SA-480M Identical except for differences in 14.1 and Table A1.1. Certification is mandatory and clarified heat treatment requirements in 12.1	- General Requirements - Flat Products						...	96	88 thru 96
SA-484/SA-484M Identical - General Requirements Wrought SS Products								94b	87 thru 94b
SA-487/SA-487M Identical	...	×	...	×	×	×	×	93	88 thru 93
SA-494/SA-494M	- See Section II, Part B								
SA-508/SA-508M Identical	...	×	...	×	×	×	×	95	87 thru 95
SA-515/SA-515M Identical	×	×	×	×	×	×	×	93	82 thru 93
SA-516/SA-516M Identical	×	×	×	×	×	×	×	90	86 thru 90
SA-517/SA-517M Identical for Grades A, B, E, F, J, P, and deletion of fusion in 1.1	...	×	...	×	×	×	...	93	87a[e1] thru 93
SA-522/SA-522M Identical	...	×	...	×	×	...	...	95	87 thru 95
SA-524 Identical	...	×	...	×	×	×	...	93	88 thru 93
SA-530/SA-530M Identical	- General Requirements for Pipe							96	88a thru 96
SA-533/SA-533M Identical	...	×	...	×	×	×	...	93	87 thru 93
SA-537/SA-537M Identical	...	×	...	×	×	...	×	96	86 thru 96
SA-540/SA-540M Identical	...	×	...	×	×	×	...	93	84a thru 93
SA-541/SA-541M Identical	...	×	...	×	×	×	×	95	87a thru 95

Specification	Book Section I	III	IV	VIII-I	VIII-2	Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
SA-542/SA-542M Identical	...	...	...	×	×	×	×	95	88 thru 95
SA-543/SA-543M Identical	...	...	...	×	×	...	...	93	87 thru 93
SA-553/SA-553M Identical	...	×	...	×	×	...	×	93	87b thru 93
SA-556/SA-556M Identical	...	...	...	×	...	...	...	90a(R95)	88 thru 90a(R95)
SA-557/SA-557M Identical	...	...	...	×	...	...	...	90a	88 thru 90a
SA-562/SA-562M Identical	...	...	...	×	...	...	...	90	82(1987) thru 90
SA-563 Identical	...	...	...	×	×	×	...	95a	84 thru 95a
SA-564/SA-564M Identical	...	×	...	×	...	×	...	92a	87b thru 92a
SA-574 Based on A325-80a and A574-82. Material conforming to A574-82 can usually be requalified to conform to this specification	...	×	...	×	...	×	...	82	...
SA-577/SA-577M Identical	- Ultrasonic Angle Beam of Plates					...	...	90	86 thru 90
SA-578/SA-578M Identical	- Ultrasonic Straight Beam of Plates					...	...	92	85 thru 92
SA-587 Identical except for deletion of 1.5	...	×	...	×	...	...	...	93	88 thru 93
SA-592/SA-592M Identical	...	×	...	×	×	×	...	89(1994)[e1]	85 thru 89(1994)[e1]
SA-609 Identical	- Ultrasonic Longitudinal Beam - Castings					...	...	91	83 thru 91
SA-612/SA-612M Identical	...	×	...	×	...	...	...	90	87 thru 90
SA-620/SA-620M Identical except for editorial changes in 6.1.1	...	...	×	×	...	...	...	92(1993)[e1]	84 thru 92(1993)[e1]
SA-638/SA-638M Identical	...	×	...	...	...	×	×	92	87 thru 92
SA-645/SA-645M Identical	...	...	...	×	×	...	×	87	87(1991)

Specification	Book Section I	III	IV	VIII-1	VIII-2	Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
SA-649/SA-649M Identical	...	...	...	...	...	...	×	94a	91a thru 94a
SA-660 Identical	×	×	...	...	...	...	...	91a	88 thru 91a
SA-662/SA-662M Identical	...	...	...	×	×	...	...	93	86 thru 93
SA-666 Identical	...	...	...	...	...	...	...	96	90 thru 96
SA-667/SA-667M Identical	...	...	...	×	...	...	...	87	87(1993)
SA-671 Identical except for additional requirements that apply as shown in Specification	...	×	...	...	...	...	×	94	85 thru 94
SA-672 Identical except for the deletion of pipe Grade M. The additional requirements apply as shown in the Specification.	...	×	...	...	...	...	...	94	81 thru 94
SA-675 Identical except for the deletion of leaded steels and the addition of a limit of 0.35% maximum on carbon content for all grades	×	×	×	×	×	×	...	90a(R95)	85 thru 90a(R95)
SA-688/SA-688M Identical	...	×	...	×	×	...	...	96	88a thru 96
SA-691 Identical except that the additional requirements apply as shown in the Specification	...	×	...	...	...	×	...	93	85a thru 93
SA-693 Identical	...	×	...	...	...	...	...	92a	88 thru 92a
SA-695 Identical for Type B only	...	×	...	×	...	...	...	90b(R95)	84 thru 90b(R95)
SA-696 Identical	...	×	...	...	...	...	...	90a(R95)[e1]	85 thru 90a(R95)[e1]
SA-703/SA-703M Identical	- General Requirements for Castings							94	87b thru 94
SA-705/SA-705M Identical	...	×	...	...	...	×	...	93	87a thru 93
SA-723/SA-723M Identical	...	×	...	...	×	...	...	94	86a thru 94
SA-724/SA-724M Identical	...	...	...	×	×	...	...	90	88 thru 90
SA-727/SA-727M Identical	...	×	...	×	×	...	...	95b	87 thru 95b
SA-731/SA-731M Identical	...	...	...	×	...	...	...	91	88 thru 91

Specification	Book Section I	III	IV	VIII-1	VIII-2	Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
SA-736/SA-736M Identical	...	...	...	...	...	...	...	88(R94)	...
SA-737/SA-737M Identical	...	×	...	×	×	...	...	87(R91)	...
SA-738/SA-738M Identical	...	×	...	×	×	...	×	90	87a thru 90
SA-739 Identical	...	×	...	×	×	...	...	90a(R95)	81a thru 90a(R95)
SA-745/SA-745M Identical except for deletion of 1.5	- Ultrasonic of Stainless Steel Forgings						...	94	...
SA-747/SA-747M Identical	...	...	...	×	...	...	...	93	86 thru 93
SA-748/SA-748M Identical	...	...	...	×	...	...	...	87	...
SA-751/SA-751M Identical	- Chemical Analysis Test Methods for Steel							95	89a thru 95
SA-765/SA-765M Identical	...	...	...	×	×	...	...	94	...
SA-770/SA-770M Identical	- Tension Testing of Steel Plates					...	×	86	86(1990)[e1]
SA-781/SA-781M Identical	- Common Requirements for Castings					...	...	94a	87a thru 94a
SA-788 Identical	- General Requirements for Forgings					...	...	94	87 thru 94
SA-789/SA-789M Identical	...	...	...	×	...	...	×	95	88a thru 95
SA-790/SA-790M Identical	...	...	...	×	...	...	×	95	88 thru 95
SA-803/SA-803M Identical	...	...	...	×	×	...	...	96	...
SA-812/SA-812M Identical	...	...	...	×	×	...	...	93	83 thru 93
SA-813/SA-813M Identical except for clarified heat treatment requirements in 4.2.2	...	×	...	×	×	...	...	95	88a thru 95
SA-814/SA-814M Identical except for clarified heat treatment requirements in 5.2.2	...	×	...	×	×	...	...	95	88a thru 95
SA-815/SA-815M Identical	...	...	...	...	...	...	...	95a	86 thru 96[e1]

A99

Specification	Book Section I	III	IV	VIII-1	VIII-2	Nuc. Code Case	Non Nuc. Code Case	Latest Adopted ASTM	Other Acceptable ASTM Editions
SA-832/SA-832M	...	...	...	×	×	...	...	95	84(1989) thru 95
Identical except for editorial difference in Table 1									
SA-834	- Common Requirements for Iron Castings					...	...	94	84 thru 94
Identical									
SA-836/SA-836M	...	...	...	×	...	...	×	95b	87a thru 95b
Identical except for editorial differences in 3.1.2, 14.1, and Table 3									
SA-841/SA-841M	...	...	...	...	...	...	...	90	88 thru 90
Identical									
SA-905	...	...	...	...	...	...	...	93	91 thru 93
Identical									
SF-568	- Threaded Metric Fasteners				...	...	...	93a	...
Identical except for editorial difference in para. 3.1.7									

APPENDIX B
NONMANDATORY GUIDELINES ON MULTIPLE MARKING OF MATERIALS

B-100 BACKGROUND

A common inquiry topic is the permissibility of using material that is identified with two or more specifications (or grades, classes, or types), even if they have different strengths, or even if one of them is not permitted for use in the construction code of application. The Committee has addressed variants of these questions in several interpretations: I-89-11, IIA-92-08, VIII-1-89-269, and VIII-1-89-197.

B-200 GUIDELINES

The construction codes individually define what materials may be used in boilers, vessels, and components constructed in compliance to their rules. If a material meets all of the requirements for a specification for which it is marked, including documentation, if any, and if it meets all requirements for use imposed by the construction code, it may be used. The construction codes, in general, do not address the case of materials marked with more than one specification, grade, class, or type, so these guidelines are offered for clarification.

B-210 ACCEPTABILITY OF MULTIPLE MARKING

Dual or multiple marking is acceptable, as long as the material so marked meets all of the requirements of all the specifications, grades, classes, and types with which it is marked.

All of the measured and controlled attributes of the multiply-marked grades or specifications must overlap (e.g., chemistry, mechanical properties, dimensions, and tolerances) and the material so marked must exhibit values that fall within the overlaps. Further, the controlled but unmeasured attributes of the specifications or grades must overlap (e.g., melting practices, heat treatments, and inspection.)

Many specifications or grades have significant overlap of chemistry ranges or properties. It is common for material manufacturers to produce materials that satisfy more than one specification, grade, class, or type. Examples are SA-53 and SA-106 (some grades and classes); SA-213 TP304L and TP304; SA-213 TP304 and 304H; and SA-106 B and SA-106 C.

B-220 PROHIBITION ON MULTIPLE MARKING

Dual or multiple marking is not acceptable if two or more specifications to which the material is marked have mutually exclusive requirements.

This prohibition includes more than just chemistry and property requirements. Examples are SA-515 and SA-516; the former requires melting to coarse grain practice while the latter requires melting to fine grain practice. Another example is SA-213 TP304L and TP304H; the carbon content ranges of these grades have no overlap.

B-230 GRADE SUBSTITUTION

Grade substitution is not permitted. Grade substitution occurs when: (1) the material contains an element (other than nitrogen) that is unspecified for one of the grades marked; and (2) the amount of that element present in the material meets the minimum and maximum composition limits for that element in another grade of a specification contained in Section II, Part A or Part B, whether or not it is also so marked.

For example, a material meets all of the composition limits for SA-240 304, contains 0.06C and 0.02N, but also contains 0.45% Ti. This material cannot be marked or provided as meeting SA-240 304 because the Ti

content meets the requirements of SA-240 321 [which is, Ti greater than 5 × (C + N) but less than 0.7.].

Another material, with identical composition, except 0.35% Ti, may be marked SA-240 304 because the Ti content does not meet the minimum requirement for 321. The Ti content is just a residual.

B-240 MARKING SELECTION

If a material is marked with specifications, grades, classes, or types, it may be used with the allowable stresses, design stress intensities, or ratings appropriate for any of the markings on the material, as long as the material specification, grade, class, and type is permitted by the code of construction governing the boiler, vessel, or component in which the material is to be used. However, once the designer has selected which marking applies (specification, grade, class types, etc.), the designer must use all the design values appropriate for that selection and may not mix and match values from any other specifications, grades, classes, types, etc., with which the material may be marked.

B-250 OTHER MARKINGS

Any other markings, such as marking of non-ASME or non-ASTM material specifications, have no relevance, even if those markings are for materials explicitly prohibited by the construction code being used. That is, as long as the *one* marking, and the documentation required by the material and by the construction code, shows that it meets all the requirements for use of that material in that construction code, any additional markings are irrelevant.

SI UNITS

The 1998 Edition of the Boiler and Pressure Vessel Code is based on U.S. Customary (ft-lb) units of measurement which are to be regarded as the standard. This supplement is provided as a convenience to the Code user and contains SI conversion factors for units contained in the Code.

LIST OF SI UNITS FOR USE WITH ASME BOILER AND PRESSURE VESSEL CODE[1]

Quantity	Unit	Symbol	Other Units or Limitations
Space and Time			
plane angle	radian	rad	degree (decimalized)
length	meter	m	
area	square meter	m^2	
volume	cubic meter	m^3	liter (L) for liquid only (use without prefix other than in milliliter, mL)
time	second	s	minute (min), hour (h), day (d), week, and year
Periodic and Related Phenomena			
frequency	hertz	Hz	revolutions per second (r/s)
rotational frequency	revolutions per second	s^{-1}	revolutions per minute (r/m)
Mechanics			
mass	kilogram	kg	
density	kilogram per cubic meter	kg/m^3	
moment of inertia	kilogram · $meter^2$	$kg \cdot m^2$	
force	newton	N	
moment of force (torque)	newton-meter	$N \cdot m$	
pressure and stress	pascal	Pa	(pascal = newton per square meter)
energy, work	joule	J	kilowatt-hour (kW · h)
power	watt	W	
impact strength	joule	J	
section modulus	$meter^3$	m^3	
moment of section (second moment of area)	$meter^4$	m^4	
fracture toughness	$Pa \cdot \sqrt{m}$		
Heat			
temperature — thermodynamic [Note (2)]	kelvin	K	degree Celsius (°C)
temperature — other than thermodynamic	degree Celsius	°C	kelvin (K)
linear expansion coefficient	meter per meter-kelvin	K^{-1}	$°C^{-1}$
quantity of heat	joule	J	
heat flow rate	watt	W	
thermal conductivity	watt per meter-kelvin	$W/(m \cdot K)$	$W/(m \cdot °C)$
thermal diffusivity	square meter per second	m^2/s	
specific heat capacity	joule per kilogram-kelvin	$J/(kg \cdot K)$	$J/(kg \cdot °C)$
Electricity and Magnetism			
electric current	ampere	A	
electric potential	volt	V	
current density	ampere per $meter^2$	A/m^2	
magnetic field strength	ampere per meter	A/m	

NOTES:

(1) Conversion factors between SI units and U.S. customary are given in SI-1, "ASME Orientation and Guide for Use of SI (Metric) Units," and ASTM E 380.

(2) Preferred use for temperature and temperature interval is degrees Celsius (°C), except for thermodynamic and cryogenic work where kelvins may be more suitable. For temperature interval, 1 K = 1°C exactly.

COMMONLY USED CONVERSION FACTORS
(For Others See ASTM E 380) [See Note (1)]

Quantity	To Convert From	To	Multiply by [Note (2)]	
plane angle	degree	rad	1.745 329	E−02
length	in	m	2.54*	E−02
	ft	m	3.048*	E−01
	yd	m	9.144*	E−01
area	in^2	m^2	6.451 6*	E−04
	ft^2	m^2	9.290 304*	E−02
	yd^2	m^2	8.361 274	E−01
volume	in^3	m^3	1.638 706	E−05
	ft^3	m^3	2.831 685	E−02
	US gallon	m^3	3.785 412	E−03
	Imperial gallon	m^3	4.546 09	E−03
	liter	m^3	1.0*	E−03
mass	lbm	kg	4.535 924	E−01
	ton (metric) (mass)	kg	1.000 00*	E+03
	ton (short 2000 lbm)	kg	9.071 847	E+02
force	kgf	N	9.806 65*	E+00
	lbf	N	4.448 222	E+00
bending, torque	kgf · m	N · m	9.806 65*	E+00
	lbf · in	N · m	1.129 848	E−01
	lbf · ft	N · m	1.355 818	E+00
pressure, stress	kgf/m^2	Pa	9.806 65*	E+00
	lbf/ft^2	Pa	4.788 026	E+01
	lbf/in^2 (psi)	Pa	6.894 757	E+03
	$kips/in^2$	Pa	6.894 757	E+06
	bar	Pa	1.0*	E+05
energy, work	Btu (IT) [Note (3)]	J	1.055 056	E+03
	ft · lbf	J	1.355 818	E+00
power	hp (550 ft · lbf/s)	W	7.456 999	E+02
fracture toughness	ksi $\sqrt{in}$	Pa · $\sqrt{m}$	1.098 843	E+06
temperature	°C	K	$t_K = t_C + 273.15$	
	°F	K	$t_K = (t_F + 459.67)/1.8$	
	°F	°C	$t_C = (t_F - 32)/1.8$	
temperature interval	°C	K	1.0*	E+00
	°F	K or °C	5.555 555	E−01

NOTES:
(1) Care should be taken when converting formulas or equations that contain constant terms or factors. The value of these terms must be understood and may also require conversion.
(2)(a) Relationships that are exact in terms of the base units are followed by a single asterisk.
(b) The factors are written as a number greater than 1 and less than 10 with 6 or less decimal places. The number is followed by the letter E (for exponent), a plus or minus symbol, and two digits which indicate the power of 10 by which the number must be multiplied to obtain the correct value. For example: 3.523 907 E−02 is $3.523\ 907 \times 10^{-2}$ or 0.035 239 07.
(3) International Table.

SUMMARY OF CHANGES

Addenda to the 1998 Edition of the Code are issued in the form of replacement pages. Revisions, additions, or deletions are incorporated directly into the affected pages. It is advisable, however, that all replaced pages be retained for reference.

Replace or insert the pages listed. Changes given below are identified on the pages by a margin note, **A99**, placed next to the affected area. Revisions to the 1998 Edition are indicated by **98**. For the listing below, the *Page* references the affected area. A margin note, **A99**, placed next to the heading indicates *Location*. Revisions are listed under *Change*.

Location	*Page*	*Change*
Listing of Sections	iii	Title to Section III, Division 3 revised
Roster	xv–xxiv	Updated to reflect A99
Contents	xxxi–xxxviii	Updated to reflect A99
Appendix A	xli–l	Updated to reflect A99
SA-240	363	Subtitle revised
	364	Para. 6 added
	365–370.1	Tables 1 and 2 revised
SA-372/SA-372M	677	Subtitle and para. 1.1 revised
SA-414/SA-414M	739	Subtitle revised
	740	Para. 5.3 revised
	742	Table 1 revised
SA-815/SA-815M	1397–1406	(1) Subtitle revised (2) Paras. 6.2.4 and 7.2.2 added (3) Para. 7.2 revised (4) Para. 7.3 redesignated to 7.2.1 and revised (5) Tables 1 and 3 revised
SA/JIS G3118	1449	Added

NOTE:
Volume 44 of the Interpretations to Section II, Part A of the ASME Boiler and Pressure Vessel Code follows the last page of the Addenda.

SPECIFICATION FOR GENERAL REQUIREMENTS FOR ROLLED STEEL PLATES, SHAPES, SHEET PILING, AND BARS FOR STRUCTURAL USE

SA-6/SA-6M

(Identical with ASTM Specification A 6/A 6M-93b except for the deletion of Annex A2.) 98

1. Scope

1.1 This specification covers a group of common requirements that, unless otherwise specified in the material specification, apply to rolled steel plates, shapes, sheet piling, and bars under each of the following specifications issued by ASTM:

ASTM Designation	Title of Specification
A 36/A 36M	Structural Steel
A 131/A 131M	Structural Steel for Ships
A 242/A 242M	High-Strength Low-Alloy Structural Steel
A 283/A 283M	Low and Intermediate Tensile Strength Carbon Steel Plates
A 284/A 284M	Low and Intermediate Tensile Strength Carbon-Silicon Steel Plates for Machine Parts and General Construction
A 328/A 328M	Steel Sheet Piling
A 514/A 514M	High-Yield Strength, Quenched and Tempered Alloy Steel Plate Suitable for Welding
A 529/A 529M	Structural Steel with 42 ksi (290 MPa) Minimum Yield Point (½ in. [13 mm] Maximum Thickness)
A 572/A 572M	High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality
A 573/A 573M	Structural Carbon Steel Plates of Improved Toughness
A 588/A 588M	High-Strength Low-Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point to 4 in. [100 mm] Thick
A 633/A 633M	Normalized High-Strength Low-Alloy Structural Steel
A 656/A 656M	Hot-Rolled Structural Steel, High-Strength Low-Alloy Plate with Improved Formability
A 678/A 678M	Quenched and Tempered Carbon-Steel and High-Strength Low-Alloy Steel Plates for Structural Applications
A 690/A 690M	High-Strength Low-Alloy Steel H-Piles and Sheet Piling for Use in Marine Environments
A 709	Structural Steel for Bridges
A 710/A 710M	Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium and Nickel-Copper-Columbium Alloy Steels
A 769/A 769M	Electric Resistance Welded Steel Shapes
A 786/A 786M	Rolled Steel Floor Plates
A 808/A 808M	High-Strength Low-Alloy Carbon, Manganese, Columbium, Vanadium Steel of Structural Quality with Improved Notch Toughness
A 827	Plates, Carbon Steel, for Forging and Similar Applications
A 829	Plates, Alloy Steel, Structural Quality
A 830	Plates, Carbon Steel, Structural Quality, Furnished to Chemical Composition Requirements
A 852/A 852M	Quenched and Tempered Low-Alloy Structural Steel Plate
A 857	Steel Sheet Piling, Cold Formed, Light Gage
A 871/A 871M	High-Strength Low Alloy Structural Steel Plate With Atmospheric Corrosion Resistance

1.2 Annex A1 lists permissible variations in dimensions and mass (Note 1) in SI (metric) units. The

values listed are not exact conversions of the values in Tables 1 through 31 but are, instead, rounded or rationalized values. Conformance to Annex A1 is mandatory when the "M" specification designation is used.

NOTE 1—The term "weight" is used when inch-pound units are the standard; however, under SI, the preferred term is "mass."

1.3 Appendix X1 describes the production and some of the characteristics of coiled product from which structural plate may be produced.

1.4 Appendix X2 provides information on the variability of tensile properties in plates and structural shapes.

1.5 Appendix X3 provides information on weldability.

1.6 This specification also covers a group of supplementary requirements that are applicable to several of the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.7 In case of any conflict in requirements, the requirements of the individual material specification shall prevail over those of this general specification.

1.8 The purchaser may specify additional requirements that do not negate any of the provisions of this general specification or of the individual material specifications. Such additional requirements, the acceptance of which are subject to negotiation with the supplier, must be included in the order information (see Section 4).

1.9 For purposes of determining conformance with this specification and the various material specifications referenced in 1.1, values shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E 29.

1.10 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.11 This specification and the applicable material specifications are expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 673/A 673M Specification for Sampling Procedure for Impact Testing of Structural Steel

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 29 Practice Using Significant Digits in Test Data to Determine Conformance with Specifications

E 112 Test Methods for Determining Average Grain Size

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

2.2 *American Welding Society Standards:*

A5.1 Mild Steel Covered Arc-Welding Electrodes

A5.5 Low-Alloy Steel Covered Arc-Welding Electrodes

2.3 *U.S. Military Standards:*

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage

2.4 *U.S. Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *Plates* (other than floor plates or coiled product) — Flat, hot-rolled steel, classified as follows:

3.1.1.1 *When Ordered to Thickness:*

(1) Over 8 in. [200 mm] in width and 0.230 in. [over 6 mm] or over in thickness.

(2) Over 48 in. [1200 mm] in width and 0.180 in. [over 4.5 mm] or over in thickness.

3.1.1.2 *When Ordered to Weight:*

(1) Over 8 in. [200 mm] in width and 9.392 lb/ft^2 [over 47.10 kg/m^2] or heavier.

(2) Over 48 in. [1200 mm] in width and 7.350 lb/ft^2 [over 35.32 kg/m^2] or heavier.

3.1.1.3 Slabs, sheet bars, and skelp, though frequently falling in the foregoing size ranges, are not classed as plates.

3.1.1.4 Coiled product is excluded from qualification to this specification until cut to length (see 5.4.2).

3.1.2 *Shapes (Flanged Sections):*

3.1.2.1 *structural-size shapes* — rolled flanged sections having at least one dimension of the cross section 3 in. [75 mm] or greater. Structural shape size groupings used for tensile property classification are listed in Table A.

3.1.2.2 *bar size shapes* — rolled flanged sections having a maximum dimension of the cross section less than 3 in. [75 mm].

3.1.2.3 *"W" shapes* — are doubly-symmetric, wide-flange shapes used as beams or columns whose inside flange surfaces are substantially parallel. A shape having essentially the same nominal weight and dimensions as a "W" shape listed in Table A, but whose inside flange surfaces are not parallel, may also be considered a "W" shape having the same nomenclature as the tabulated shape, provided its average flange thickness is essentially the same as the flange thickness of the "W" shape.

3.1.2.4 *"HP" shapes* — are wide-flange shapes generally used as bearing piles whose flanges and webs are of the same nominal thickness and whose depth and width are essentially the same.

3.1.2.5 *"S" shapes* — doubly-symmetric shapes produced in accordance with dimensional standards adopted in 1896 by the Association of American Steel Manufacturers for American Standard beam shapes. The essential part of these standards is that the inside flange surfaces of American Standard beam shapes have approximately $16\frac{2}{3}\%$ slope.

3.1.2.6 *"M" shapes* — doubly-symmetric shapes that cannot be classified as "W," "S," or "HP" shapes.

3.1.2.7 *"C" shapes* — channels produced in accordance with dimensional standards adopted in 1896 by the Association of American Steel Manufacturers for American Standard channels. The essential part of these standards is that the inside flange surfaces of American Standard channels have approximately a $16\frac{2}{3}\%$ slope.

3.1.2.8 *"MC" shapes* — channels that cannot be classified as "C" shapes.

3.1.2.9 *"L" shapes* — shapes having equal-leg and unequal-leg angles.

3.1.3 *sheet piling* — steel sheet piling consists of rolled sections that can be interlocked, forming a continuous wall when individual pieces are driven side by side.

3.1.4 *bars* — rounds, squares, and hexagons, of all sizes; flats $\frac{13}{64}$ in. (0.2031 in.) [over 5 mm] and over in specified thickness, not over 6 in. [150 mm] in specified width; and flats 0.230 in. [over 6 mm] and over in specified thickness, over 6 to 8 in. [150 to 200 mm] inclusive, in specified width.

3.1.5 *exclusive* — when used in relation to ranges, as for ranges of thickness in the tables of permissible variations in dimensions, is intended to exclude only the greater value of the range. Thus, a range from 60 to 72 in. [1500 to 1800 mm] exclusive includes 60 in. [1500 mm], but does not include 72 in. [1800 mm].

3.1.6 *rimmed steel* — steel containing sufficient oxygen to give a continuous evolution of carbon monoxide during solidification, resulting in a case or rim of metal virtually free of voids.

3.1.7 *semi-killed steel* — incompletely deoxidized steel containing sufficient oxygen to form enough carbon monoxide during solidification to offset solidification shrinkage.

3.1.8 *capped steel* — rimmed steel in which the rimming action is limited by an early capping operation. Capping may be carried out mechanically by using a heavy metal cap on a bottle-top mold or it may be carried out chemically by an addition of aluminum or ferrosilicon to the top of the molten steel in an open-top mold.

3.1.9 *killed steel* — steel deoxidized, either by addition of strong deoxidizing agents or by vacuum treatment, to reduce the oxygen content to such a level that no reaction occurs between carbon and oxygen during solidification.

3.1.10 *groupings for tensile property classification* — in some of the material specifications, the tensile property requirements vary for different sizes of shapes due to mass effect, etc. For the convenience of those using the specifications, the various sizes of shapes have been divided into groups based on section thickness at the standard tension test location (webs of beams, channels, and zees; legs of angles; and stems of tees). The material specifications designate shape sizes by reference to the group designations. The groupings are shown in Table A.

3.1.11 *mill edge* — the normal edge produced by rolling between horizontal finishing rolls. A mill edge does not conform to any definite contour. Mill edge plates have two mill edges and two trimmed edges.

3.1.12 *universal mill edge* — the normal edge produced by rolling between horizontal and vertical finishing rolls. Universal mill plates, sometimes designated UM Plates, have two universal mill edges and two trimmed edges.

3.1.13 *sheared edge* — the normal edge produced by shearing. Sheared edge plates are trimmed on all edges.

3.1.14 *gas cut edge* — the edge produced by gas flame cutting.

3.1.15 *special cut edge* — usually the edge produced by gas flame cutting involving special practices such as preheating or postheating, or both, in order to minimize stresses, avoid thermal cracking, and reduce the hardness of the gas cut edge. In special instances, special cut edge may be used to designate an edge produced by machining.

3.1.16 *sketch* — when used to describe a form of plate, denotes a plate other than rectangular, circular, or semicircular. Sketch plates may be furnished to a radius or with four or more straight sides.

3.1.17 *normalizing* — a heat treating process in which a steel plate is reheated to a uniform temperature above the upper critical temperature and then cooled in air to below the transformation range.

4. Ordering Information

4.1 Orders should include the following information, as necessary, to adequately describe the desired material:

4.1.1 ASTM designation and grade, etc. (if applicable),

4.1.2 Name of material (shapes, plates, bars),

4.1.3 Shape designation, or size and thickness or diameter, and length,

4.1.4 Quantity (weight [mass] or number of pieces),

4.1.5 Condition, if other than as-rolled (normalized, etc.),

4.1.6 Either plates from coil or discrete cut lengths of flat product may be supplied, unless one is specifically excluded on the order (see Appendix X1),

4.1.7 Should the processor (5.4.2) intend to qualify plates cut from a coiled product as structural plates, the order to the manufacturer (5.4.1) should state the intended ASTM specification designation, grade, and type,

4.1.8 Mechanical property test report requirements, if any,

4.1.9 Thermal treatment of test specimens by the mill, if required (see 6.2 and 6.3), and

4.1.10 Supplementary requirements, if any, including any additional information called for in the supplementary requirements.

5. Manufacture

5.1 Unless otherwise specified in the material specification, the steel shall be made by the open-hearth, basic-oxygen, or electric-furnace process. Additional refining by vacuum-arc-remelt (VAR) or electroslag-remelt (ESR) is permitted.

5.2 The steel may be cast in stationary molds or may be strand cast.

5.2.1 *Strand Cast:*

5.2.1.1 When heats of the same nominal chemical composition are consecutively strand cast at one time, the heat number assigned to the cast product may remain unchanged until all of the steel in the cast product is from the following heat.

5.2.1.2 When two consecutively strand cast heats have different nominal chemical composition ranges, the manufacturer shall remove the transition material by an established procedure that positively separates the grades.

5.3 Plates are produced in either discrete cut lengths of flat product or from coils.

5.3.1 Plates produced from coil means plates that have been cut to individual lengths from a coiled product and are furnished without heat treatment. For the purposes of this paragraph, stress relieving is not considered to be a heat treatment.

5.3.2 Plates that are heat treated (except stress relieving) after decoiling shall be considered to be discrete cut lengths of flat product.

5.4 When plates are produced from coils:

5.4.1 The manufacturer directly controls one or more of the operations (that is, melting, rolling, coiling, etc.), that affect the chemical composition or the mechanical properties, or both, of the material.

5.4.2 The processor decoils, cuts to length, and marks; performs and certifies tests, examinations, repairs, inspection, or operations not intended to affect the properties of the material. The processor may

subsequently heat treat the plate (see Section 7). Specific sections of this specification for which the processor is responsible are 9, 10, 11, 12, 13, 14, 15, 18, and 19.

5.4.3 When part of a heat is rolled into discrete plates of flat product and the balance of the heat into coiled product, each part must be tested separately.

5.4.4 Plates produced from coils shall not contain splice welds, unless previously approved by the purchaser.

6. Heat Treatment

6.1 When material is required to be heat treated, the heat treatment may be performed either by the manufacturer, processor, or fabricator unless otherwise specified in the material specification.

6.2 When heat treatment is to be performed by other than the material manufacturer, the order shall so state.

6.2.1 When heat treatment is to be performed by other than the material manufacturer, the plates shall be accepted on the basis of tests made on specimens taken from full thickness coupons heat treated in accordance with the requirements specified in the material specification or on the order. If the heat-treatment temperatures are not specified, the manufacturer or processor shall heat treat the coupons under conditions he considers appropriate. The purchaser shall be informed of the procedure followed in heat treating the specimens.

6.3 When heat treatment is to be performed by the manufacturer or processor, the material shall be heat treated as specified in the material specification. The purchaser may specify the heat treatment to be used provided it is not in conflict with the requirements of the material specification.

6.4 When normalizing is to be performed by the fabricator, it may be accomplished by heating uniformly for hot forming. The temperature to which the plates are heated for hot forming shall not significantly exceed the normalizing temperature.

6.5 When no heat treatment is required, the manufacturer or processor may, at his option, heat treat the plates by normalizing, stress relieving, or normalizing and then stress relieving to meet the material specification.

6.6 If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible for improvement of the toughness, provided the plates are subsequently tempered in the temperature range from 1100 to 1300°F [595 to 705°C].

7. Chemical Analysis

7.1 *Heat Analysis* — An analysis of each heat shall be made by the manufacturer to determine the percentage of carbon, manganese, phosphorus, sulfur, and any other elements specified or restricted by the applicable specification. This analysis shall be made from a test sample preferably taken during the pouring of the heat. The heat analysis shall be reported to the purchaser or his representative and shall conform to the heat analysis requirements of the applicable specification.

7.1.1 When vacuum-arc-remelting or electroslag remelting is used, a heat is defined as all the ingots remelted from a single primary melt. The heat analysis shall be obtained from one remelted ingot, or the product of one remelted ingot, of each primary melt providing the heat analysis of the primary melt meets the heat analysis requirements of the material specification. If the heat analysis of the primary melt does not meet the heat analysis requirements of the material specification, one test sample shall be taken from the product of each remelted ingot. In either case, the analyses so obtained from the remelted material shall conform to the heat analysis requirements of the applicable specification.

7.1.2 In addition to the elements specified by the applicable specification, test reports shall include for information the chemical analyses for copper, columbium, chromium, nickel, molybdenum, silicon, and vanadium. When the amount of copper, chromium, nickel, molybdenum, or silicon is less than 0.02%, the analysis may be reported as “<0.02%.” When the amount of columbium or vanadium is less than 0.008%, the analysis may be reported as “<0.008%.”

7.2 *Product Analysis* — The purchaser may analyze finished material representing each heat. Sampling shall be in accordance with Test Methods, Practices, and Terminology A 751. The chemical composition thus determined shall conform to the requirements of the product specification subject to the product analysis tolerances in Table B. If a range is specified, the determinations of any element in a heat may not vary both above and below the specified range. Rimmed or capped steel is characterized by a lack of homogeneity in its composition, especially for the elements carbon, phosphorus, and sulfur. Therefore, the limitations for

these elements shall not be applicable unless misapplication is clearly indicated.

7.3 *Referee Analysis* — For referee purposes, Test Methods, Practices, and Terminology A 751 shall be used.

8. Metallurgical Structure

8.1 When a grain size is specified, it shall be specified as fine austenitic grain size or coarse austenitic grain size. Austenitic grain size shall be determined in accordance with Test Methods E 112.

8.2 *Coarse Austenitic Grain Size* — When coarse austenitic grain size is specified, steel having grain size number of 1 to 5 as determined by the method described in 8.1 shall be acceptable. Conformance to the specified grain size of 70% of the area examined shall constitute the basis of acceptance. One test per heat shall be made.

8.3 *Fine Austenitic Grain Size:*

8.3.1 When fine austenitic grain size is specified, steel having grain size number 5 or higher as determined by the method described in 8.1 shall be acceptable. Conformance to the specified grain size of 70% of the area examined shall constitute the basis of acceptance. One grain size test per heat shall be performed except as described in 8.3.2.

8.3.2 When aluminum is used as the grain refining element and on heat analysis the aluminum content is not less than 0.020% total aluminum, or alternately, 0.015% acid soluble aluminum, the fine austenitic grain size requirement shall be deemed fulfilled and the testing requirement of 8.1 shall be waived. The aluminum content shall be reported if the testing requirement is waived.

8.3.3 When specified on the order, one grain size test (see 8.1) per heat shall be made regardless of type or content of grain refining element. Austenitic grain size shall conform to 8.3.1.

8.3.4 Elements other than aluminum may be used for grain refining. In such instances, the grain size test of 8.1 shall be required. The content of the elements shall be reported with the heat analysis.

9. Quality

9.1 *General* — The material shall be free of injurious defects and shall have a workmanlike finish.

NOTE 2—Unless otherwise specified, structural quality steels are normally furnished in the as-rolled condition and subjected to visual inspection by the manufacturer. Non-injurious surface or internal imperfections *or both* may be present in the steel as delivered and may require conditioning by the *purchaser* to improve the appearance of the steel or in preparation for welding, coating, or other further processing.

More *restrictive* requirements may be specified by invoking supplementary requirements or by agreement between purchaser and supplier.

In the event of any material exhibiting injurious defects during subsequent fabrication, such material shall be deemed not to comply with the specification and shall be rejected and the supplier notified. (See 16.2.) Fabricators should be aware that cracks may initiate upon bending a sheared or burned edge during the fabrication process. This is not considered to be a fault of the steel but is rather a function of the induced cold-work or heat-affected zone.

The conditioning requirements in 9.2, 9.3, and 9.4 limit the conditioning allowed to be performed by the manufacturer. Conditioning of imperfections beyond the limits of 9.2, 9.3, and 9.4 may be performed by parties other than the manufacturer at the discretion of the *purchaser*.

9.2 *Plate Conditioning:*

9.2.1 Plates may be conditioned by the manufacturer or processor for the removal of imperfections or depressions on the top and bottom surfaces by grinding, provided the area ground is well faired without abrupt changes in contour and the grinding does not reduce the thickness of the plate by *(1)* more than 7% under the nominal thickness for plates ordered to weight per square foot or [mass per square metre], but in no case more than $\frac{1}{8}$ in. [3 mm]; or *(2)* below the permissible minimum thickness for plates ordered to thickness in inches or millimetres.

9.2.2 Imperfections on the top and bottom surfaces of plates may be removed by chipping, grinding, or arc-air gouging and then by depositing weld metal (see 9.5), subject to the following limiting conditions:

9.2.2.1 The chipped, ground, or gouged area shall not exceed 2% of the area of the surface being conditioned.

9.2.2.2 After removal of any imperfections preparatory to welding, the thickness of the plate at any location must not be reduced by more than 30% of the nominal thickness of the plate. (Specification A 131/A 131M restricts the reduction in thickness to 20% maximum.)

9.2.3 The edges of plates may be conditioned by the manufacturer or processor to remove injurious imperfections by grinding, chipping, or arc-air gouging and welding (see 9.5). Prior to welding, the depth of depression, measured from the plate edge inward, shall

be limited to the thickness of the plate, with a maximum depth of 1 in. [25 mm].

9.3 *Structural Size Shapes, Bar Size Shapes, and Steel Sheet Piling Conditioning:*

9.3.1 These products may be conditioned by the manufacturer for the removal of injurious imperfections or surface depressions by grinding, or chipping and grinding, provided the area ground is well faired without abrupt changes in contour and the depression does not extend below the rolled surface by more than *(1)* 1/32 in. [1 mm], for material less than 3/8 in. [10 mm] in thickness; *(2)* 1/16 in. [2 mm], for material 3/8 to 2 in. [10 to 50 mm] inclusive in thickness; or *(3)* 1/8 in. [3 mm], for material over 2 in. [50 mm] in thickness.

9.3.2 Imperfections that are greater in depth than the limits previously listed may be removed and then weld metal deposited (see 9.5), subject to the following limiting conditions:

9.3.2.1 The total area of the chipped or ground surface of any piece prior to welding shall not exceed 2% of the total surface area of that piece.

9.3.2.2 The reduction of thickness of the material resulting from removal of imperfections prior to welding shall not exceed 30% of the nominal thickness at the location of the imperfection, nor shall the depth of depression prior to welding exceed 1 1/4 in. [32 mm] in any case except as noted in 9.3.2.3.

9.3.2.3 The toes of angles, beams, channels, and zees, and the stems and toes of tees, may be conditioned by grinding, chipping, or arc-air gouging and welding (see 9.5). Prior to welding, the depth of depression, measured from the toe inward, shall be limited to the thickness of the material at the base of the depression, with a maximum depth limit of 1/2 in. [12.5 mm].

9.3.2.4 The interlock of any sheet piling section may be conditioned by welding (see 9.5) and grinding to correct or build up the interlock at any location not to exceed 2% of the total surface area.

9.4 *Bar Conditioning:*

9.4.1 Bars may be conditioned by the manufacturer for the removal of imperfections by grinding, chipping, or some other means, provided the conditioned area is well faired and the affected sectional area is not reduced by more than the permissible variations prescribed in the applicable tables designated in Section 13.

9.4.2 Imperfections that are greater in depth than the limitations of 9.4.1 may be removed by chipping or grinding and then by depositing weld metal (see 9.5) subject to the following limiting conditions:

9.4.2.1 The total area of the chipped or ground surface of any piece, prior to welding, shall not exceed 2% of the total surface area of the piece.

9.4.2.2 The reduction of sectional dimension of a round, square, or hexagon bar, or the reduction in thickness of a flat bar, resulting from removal of an imperfection, prior to welding, shall not exceed 5% of the nominal dimension or thickness at the location of the imperfection.

9.4.2.3 For the edges of flat bars, the depth of the conditioning depression prior to welding shall be measured from the edge inward and shall be limited to a maximum depth equal to the thickness of the flat bar or 1/2 in. [12.5 mm], whichever is less.

9.5 *Repair by Welding:*

9.5.1 *Steels Other Than Quenched and Tempered:*

9.5.1.1 All welding shall be performed by competent welders using low hydrogen welding electrodes conforming to both the proper series and latest issue of AWS Specification A5.1 or AWS Specification A5.5. The electrodes shall be protected from moisture during storage and use.

9.5.1.2 The manufacturer or processor shall establish and follow documented welding procedures that are appropriate for the material being welded.

9.5.2 *Quenched and Tempered Steels:*

9.5.2.1 When so specified in the purchase order, prior approval for repair by welding shall be obtained from the purchaser.

9.5.2.2 The manufacturer or processor shall establish and follow the documented welding procedures that are appropriate for the material being welded. When specified on the purchase order, such procedures shall be subject to approval by the purchaser. The welding operator shall be competent to follow such procedures.

9.5.2.3 After removal of any imperfections and prior to welding, the cavity shall be examined by a magnetic particle method or a liquid penetrant method to ensure that the imperfection has been completely removed. When magnetic particle examination is employed, the cavity shall be examined parallel and normal to the length of the cavity.

9.5.2.4 Electrodes shall be protected from moisture during storage and use.

9.5.2.5 Electrodes and base metal shall be free of hydrogen-producing contaminants such as oil, grease, or other organic materials. The base metal shall be maintained in a dry condition during welding.

9.5.2.6 For material in its heat-treated condition, all welding shall be performed using either the shielded metal-arc (SMA) or gas metal-arc (GMA) process. For SMA welding, low hydrogen electrodes conforming to the latest edition of AWS Specification A5.5 shall be employed. The electrodes shall be selected to provide weld-metal deposits compatible with the minimum specified base metal properties. Moisture content shall not exceed the tolerable level for the steel being welded. For GMA welding, any composition that provides weld-metal deposits compatible with the minimum specified base metal properties may be employed. Gases used for shielding shall be of welding quality. When weld repairs by either process are to be post-weld heat treated, special care must be exercised in selection of electrodes to avoid those compositions which embrittle as a result of such heat treatment.

9.5.2.7 The heat-affected zone of quenched and tempered alloy steels may be affected adversely by excessive heat input or excessive preheating, or both. Similarly, insufficient preheat and heat input in the welding of quenched and tempered alloy steels may result in undesirable defects. Therefore, suitable combinations of heat input and preheat (including interpass temperature) shall be employed.

9.5.2.8 For material that is to be quenched and tempered after repair-welding, electrodes for SMA or GMA welding shall be selected to provide weld deposits whose mechanical properties after heat treatment meet the requirements of the base metal.

9.5.2.9 Repairs on material that is subsequently thermally treated at the mill shall be examined after heat treatment; repairs on material that is not subsequently thermally treated at the mill shall be examined no sooner than 48 hr after welding. In either case the repaired area shall be examined by one of the methods and in the same manner prescribed in 9.5.2.3.

9.5.2.10 The location of weld repairs shall be marked on the finished piece.

9.5.3 *Repair Quality* — The welds and adjacent heat-affected zone shall be sound and free of cracks, the weld metal being thoroughly fused to all surfaces and edges without undercutting or overlap. Any visible cracks, porosity, lack of fusion, or undercut in any layer shall be removed prior to deposition of the succeeding layer. Weld metal shall project at least $\frac{1}{16}$ in. (2 mm) above the rolled surface after welding, and the projecting metal shall be removed by chipping or grinding, or both, to make it flush with the rolled surface, and to produce a workmanlike finish.

9.5.4 *Inspection of Repair* — The manufacturer or processor shall maintain an inspection program to inspect the work to see that:

9.5.4.1 Imperfections have been completely removed,

9.5.4.2 The limitations specified above have not been exceeded,

9.5.4.3 Established welding procedures have been followed, and

9.5.4.4 Any weld deposit is of acceptable quality as defined above.

10. Test Methods

10.1 All tests shall be conducted in accordance with Test Methods and Definitions A 370.

10.2 Yield strength may be determined either by the 0.2% offset method or by the 0.5% extension under load method unless otherwise stated in the material specification.

10.3 *Rounding Procedures* — For purposes of determining conformance with the specification, a calculated value shall be rounded to the nearest 1 ksi [5 MPa] tensile and yield strength, and to the nearest unit in the right-hand place of figures used in expressing the limiting value for other values in accordance with the rounding method given in Practice E 29.

10.4 For full-section test specimens of angles, the cross-sectional area used for calculating the yield and tensile strengths shall be a theoretical area calculated on the basis of the weight of the test specimen (see 13.1).

11. Tension Tests

11.1 *Condition* — Test specimens shall be prepared for testing from the material in its delivered condition except that test specimens for heat-treated material may be from a separate piece of full thickness or full section from the same heat similarly treated.

11.1.1 When the plate is heat treated with a cooling rate faster than still-air cooling from the austenitizing temperature, one of the following shall apply in addition to other requirements specified herein:

11.1.1.1 The gage length of the tension test specimen shall be taken at least 1*T* from any as-heat treated edge where *T* is the thickness of the plate and shall be at least ½ in. [12.5 mm] from flame cut or heat-affected-zone surfaces.

11.1.1.2 A steel thermal buffer pad, 1*T* by 1*T* by at least 3*T*, shall be joined to the plate edge by a partial penetration weld completely sealing the buffered edge prior to heat treatment.

11.1.1.3 Thermal insulation or other thermal barriers shall be used during the heat treatment adjacent to the plate edge where specimens are to be removed. It shall be demonstrated that the cooling rate of the tension test specimen is no faster than, and not substantially slower than, that attained by the method described in 11.1.1.2.

11.1.1.4 When test coupons cut from the plate but heat treated separately are used, the coupon dimensions shall be not less than 3*T* by 3*T* by *T* and each tension specimen cut from it shall meet the requirements of 11.1.1.1.

11.1.1.5 If cooling rate data for the plate and cooling rate control devices for the test specimens are available, the test specimens may be heat treated separately in the device. This method shall require prior approval of the purchaser.

11.2 *Orientation* — For plates wider than 24 in. [600 mm], test specimens shall be taken such that the longitudinal axis of the specimen is transverse to the final direction of rolling of the plate. Test specimens for all other products shall be taken such that the longitudinal axis of the specimen is parallel to the final direction of rolling.

11.3 *Location:*

11.3.1 *Plates* — Test specimens shall be taken from a corner of the plate.

11.3.2 *Shapes* — Test specimens shall be selected from the webs of beams, channels, and zees, from the legs of angles and bulb angles, and from the stems of rolled tees. Alternatively, test specimens for angles may consist of the full section, provided that the elongation acceptance criteria are increased accordingly. (See 11.6.2.)

11.3.3 *Bars:*

11.3.3.1 Test specimens for bars to be used for pins and rollers less than 3 in. [75 mm] in diameter shall be taken so that the axis is midway, if practicable, between the center and the surface. Test specimens for pins and rollers 3 in. [75 mm] and over in diameter should be taken so that the axis is 1 in. [25 mm] from the surface.

11.3.3.2 Test specimens for bars other than those covered by 11.3.3.1 shall be taken as specified in Annex AI of Test Methods and Definitions A 370.

11.4 *Number of Tests* — Except as specified in 11.4.2, two tests shall be made from each heat in each strength gradation, where applicable, with the test coupons being taken from different as-produced pieces.

11.4.1 *Thickness Variations Requiring Thick/Thin Testing:*

11.4.1.1 When the entire product of a heat of the same strength gradation is limited to material 2 in. [50 mm] and under in thickness, and this material differs ⅜ in. [10 mm] or more in thickness, one test shall be made from at least the thickest and thinnest material rolled regardless of weight [or mass] represented.

11.4.1.2 When the entire product of a heat of the same strength gradation is limited to material over 2 in. [50 mm] in thickness, and this material differs 1 in. [25 mm] or more in thickness, one test shall be made from at least the thickest and thinnest material rolled regardless of weight [or mass] represented.

11.4.1.3 When the product of a heat of the same strength gradation contains material both over and under 2 in. [50 mm] in thickness, and this material differs ⅜ in. [10 mm] or more in thickness, one test shall be made from at least the thickest and thinnest material rolled regardless of weight [or mass] represented.

11.4.2 *Plates Provided from Coils:*

11.4.2.1 When plates are provided from coils, tension tests shall be taken from not less than two coils from each heat and each strength gradation where applicable, if more than one coil from the heat is to be qualified by the tension tests. If only one coil from a heat is to be qualified, tests need only be taken from the coil to be qualified.

11.4.2.2 When the material from one heat and one strength gradation differs 1/16 in. [2 mm] or more in thickness, tests shall be made from both the thickest

and the thinnest material rolled in that strength gradation regardless of the number of coils represented.

11.4.2.3 Two tension tests shall be taken from each coil tested. One tension-test specimen shall be taken immediately prior to the first plate produced to the qualifying specification and a second test shall be taken from the approximate center lap. If, during decoiling, the amount of material decoiled is less than that required to reach the approximate center lap, the second test for the qualification of a particular shipment may be taken from a location adjacent to the end of the innermost portion shipped. For successive shipments from the same coil, an additional test shall be taken adjacent to the innermost portion shipped until a test is obtained from the approximate center lap.

11.5 *Preparation:*

11.5.1 *Plates:*

11.5.1.1 Tension test specimens for plates ¾ in. [20 mm] and under in thickness shall be the full thickness of the plates. The test specimens shall conform to the requirements of Fig. 3 of Test Methods and Definitions A 370 for either 1½ in. [40 mm] wide specimen or the ½ in. [12.5 mm] wide specimen.

11.5.1.2 For plates up to 4 in. [100 mm], inclusive, in thickness, tension test specimens may be the full thickness of the material and conform to the requirements of Fig. 3 of Test Methods and Definitions A 370, 1½ in. [40 mm] wide specimen, when adequate testing machine capacity is available, except as required in 11.5.1.4.

11.5.1.3 For plates over ¾ in. [20 mm] in thickness, except as permitted in 11.5.1.2, tension test specimens shall conform to the requirements as shown in Fig. 4 of Test Methods and Definitions A 370, for the 0.500 in. [12.5 mm] diameter specimen. The axis of the specimen shall be located, as nearly as practicable, midway between the center of thickness and the top or bottom surface of the plate.

11.5.1.4 Test specimens for quenched and tempered plates over 1½ in. [40 mm] in thickness shall conform to the requirements as shown in Fig. 4 of Test Methods and Definitions A 370, for the 0.500 in. [12.5 mm] diameter specimen. The axis of the specimen shall be located, as nearly as practicable, midway between the center of thickness and the top or bottom surface of the plate.

11.5.2 *Shapes:*

11.5.2.1 Except when angles are tested in full section, tension test specimens for materials ¾ in. [20 mm] and under in thickness shall be the full thickness of the material. The test specimen shall conform to the requirements of Fig. 3 of Test Methods and Definitions A 370 for either the 1½ in. [40 mm] wide specimen or the ½ in. [12.5 mm] wide specimen.

11.5.2.2 For material up to 4 in. [100 mm], inclusive, in thickness, tension test specimens may be the full thickness of the material and conform to the requirements of Fig. 3 of Test Methods and Definitions A 370, for the 1½ in. [40 mm] wide specimen, when adequate testing machine capacity is available.

11.5.2.3 For material over ¾ in. [20 mm] in thickness, except as permitted in 11.5.2.2, tension test specimens shall conform to the requirements as shown in Fig. 4 of Test Methods and Definitions A 370, for the 0.500 in. [12.5 mm] diameter specimen. The axis of the specimen shall be located, as practicable, midway between the center of thickness and the top or bottom surface of the material.

11.5.3 *Bars:*

11.5.3.1 Except as otherwise provided below, test specimens for bars shall be in accordance with Annex A1 of Test Methods and Definitions A 370.

11.5.3.2 Except as provided in 11.5.3.5, test specimens for bars ¾ in. [20 mm] and under in thickness may conform to the requirements of Fig. 3 of Test Methods and Definitions A 370 for either the 1½ in. [40 mm] wide specimen or the ½ in. [12.5 mm] wide specimen.

11.5.3.3 Except as provided in 11.5.3.5, test specimens for bars over ¾ in. [20 mm] in thickness or diameter may conform either to the requirements for the 1½ in. [40 mm] or ½ in. [12.5 mm] wide specimen of Fig. 3 of Test Methods and Definitions A 370, or to the requirements for the 0.500 in. [12.5 mm] diameter specimen of Fig. 4 of Test Methods and Definitions A 370.

11.5.3.4 Test specimens for bars other than those to be used for pins and rollers may be machined to a thickness or diameter of at least ¾ in. [20 mm] for a length of at least 9 in. [230 mm].

11.5.3.5 Test specimens for bars to be used for pins and rollers shall conform to the requirements of Fig. 4 of Test Methods and Definitions A 370 for the ½ in. [12.5 mm] diameter specimen.

11.6 *Elongation Requirement Adjustments:*

11.6.1 Due to the specimen geometry effect encountered when using the rectangular tension test specimen for testing thin material, adjustments in elongation requirements must be provided for thicknesses under 0.312 in. [8 mm]. Accordingly, the following deductions from the base elongation requirements shall apply.

Nominal Thickness Range, in. [mm]	Elongation Deduction, %
0.300–0.311 [7.70–7.99]	0.5
0.287–0.299 [7.40–7.69]	1.0
0.275–0.286 [7.10–7.39]	1.5
0.262–0.274 [6.70–7.09]	2.0
0.250–0.261 [6.40–6.69]	2.5
0.243–0.249 [6.10–6.39]	3.0
0.230–0.242 [5.80–6.09]	3.5
0.218–0.229 [5.50–5.79]	4.0
0.205–0.217 [5.10–5.49]	4.5
0.194–0.204 [4.80–5.09]	5.0
0.180–0.193 [4.50–4.79]	5.5

11.6.2 Due to the specimen geometry effect encountered when using full-section test specimens for angles, the elongation requirements for structural-size angles shall be increased by six percentage points when full-section test specimens are used.

11.6.3 Due to the inherently lower elongation that is obtainable in thicker material, adjustments in elongation requirements must be provided. For material over 3.5 in. [90 mm] in thickness, a deduction of 0.5% from the specified percentage of elongation in 2 in. [50 mm] shall be made for each 0.5 in. [12.5 mm] increment of thickness over 3.5 in. [90 mm]. This deduction shall not exceed 3%. Accordingly, the following deductions from the base elongation requirements shall apply.

Nominal Thickness Range, in. [mm]	Elongation Deduction, %
3.500–3.999 [90.00–102.49]	0.5
4.000–4.499 [102.50–114.99]	1.0
4.500–4.999 [115.00–127.49]	1.5
5.000–5.499 [127.50–139.99]	2.0
5.500–5.999 [140.00–152.49]	2.5
6.000 and thicker [152.50 and thicker]	3.0

11.6.4 A characteristic of certain types of alloy steels is a local disproportionate increase in the degree of necking down or contraction of the specimens under tension test, resulting in a decrease in the percentage of elongation as the gage length is increased. The effect is not so pronounced in the thicker plates. On such material, when so stated in the material specification for plates up to $^{3}/_{4}$ in. [20 mm], inclusive, in thickness, if the percentage of elongation of an 8 in. or 200 mm gage length test specimen falls not more than 3% below the amount prescribed, the elongation shall be considered satisfactory provided the percentage of elongation in 2 in. [50 mm] across the break is not less than 25%.

11.6.5 The tensile requirements tables in many of the specifications covered by these general requirements specify elongation requirements in both 8 in. [200 mm] and 2 in. [50 mm] gage lengths. Unless otherwise provided in the individual plate specification, it is not the intent that both requirements apply simultaneously and that the elongation be determined in both gage lengths. Instead, it is intended that the elongation be determined only in the gage length appropriate for the test specimen used. After selection of the appropriate gage length, the elongation requirement for the alternative gage length shall be deemed not applicable.

11.7 *Yield Strength Application:*

11.7.1 When test specimens do not exhibit a well-defined disproportionate yield point, yield strength shall be determined and substituted for yield point.

11.7.2 When test specimens do exhibit a well-defined disproportionate yield point, as an option, yield strength may be substituted for yield point.

11.7.3 Yield strength shall be determined either by the 0.2% offset method or by the 0.5% extension-under-load method.

11.8 *Product Tension Tests* — This specification does not provide requirements for product tension testing subsequent to shipment (see 14.1). Therefore, the requirements of 11.1 through 11.7 and Section 15 apply only for tests conducted at the place of manufacture prior to shipment. Compliance to Specification A 6/A 6M and the individual material specifications by a manufacturer does not preclude the possibility that product tension test results may vary outside specified ranges. The tensile properties will vary within the same heat or piece, be it as-rolled, control-rolled, or heat-treated. The purchaser should, therefore, be aware that tension testing according to the requirements of Specification A 6/A 6M does not provide assurance that all products of a heat will be identical in tensile properties with the products tested. If the purchaser wishes to have more confidence than that provided by Specification A 6/A 6M testing procedures, additional testing or requirements, such as Supplementary Requirement S4, should be imposed.

11.8.1 Appendix X2 provides additional information on the variability of tensile properties in plates and structural shapes.

12. Identification of Material

98 **12.1** *Plates* — Each plate shall be steel die-stamped, marked, or stenciled in one place with specification number (year-date not required), grade, heat number, manufacturer's name, brand, or trademark (mill identification marks), size, and thickness. For plates provided from coils, the processor identity rather than that of the manufacturer shall be used. However, in the case of secured lifts of plates $\frac{3}{8}$ in. [10 mm] (or of material specified for bridge construction $\frac{5}{16}$ in. [8 mm]) and under in thickness of all sizes, and of plates 36 in. [900 mm] and under in width in all thicknesses, such markings may be placed on only the top piece of each lift, or may be shown on a substantial tag attached to each lift, unless otherwise specified. See also 12.6.

12.2 *Shapes* — Shapes shall be marked with the heat number, size of section, length, and mill identification marks on each piece. Either the manufacturer's name, brand, or trademark (mill identification marks) shall be shown in raised letters at intervals along the length. In addition, shapes shall be identified with the specification number (year-date not required) and grade, either by marking each piece individually or, if bundled, by attaching a substantial tag to the bundle. Small shapes with the greatest cross-sectional dimension not greater than 6 in. [150 mm] may be bundled for shipment with each lift marked or tagged showing the previously listed identification. See also 12.5.

12.3 *Steel Sheet Piling* — Steel sheet piling shall be marked with the heat number, size of section, length, and mill identification marks on each piece. Either the manufacturer's name, brand, or trademark (mill identification marks) shall be shown in raised letters at intervals along the length.

12.4 *Bars* — Bars of all sizes, when loaded for shipment, shall be properly identified with the name or brand of manufacturer (mill identification marks), purchaser's name and order number, the specification number, grade number where appropriate, size and length, weight of lift, and the heat number for identification. Unless otherwise specified, the method of marking is at the manufacturer's option and may be made by hot stamping, cold stamping, painting, or marking tags attached to the lifts of bars. Bars are not required to be die stamped.

12.5 *Bar Coding* — In addition to the requirements in 12.1, 12.2, 12.3, and 12.4, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team. 98

12.6 *Specification Identification* — In addition to the requirements of 12.1 or 12.2 material ordered to one of the specifications and grades for which a color code is given in 12.6.3 shall be marked with the applicable specification number and grade. The year-date of the specification to which the material is furnished need not be included in the marking. Color identification shall be applied as stated in 12.6.1, 12.6.2, and 12.6.3. 98

12.6.1 *Plates* — When specified by the purchaser, each plate (except for plates in secured lifts) shall be marked with the color designated in 12.6.3 along one edge or on the rolled surface within 12 in. [300 mm] of the heat number identification. Plates in secured lifts may have the color identification marked with a vertical stripe for the full height of the lift. Each plate in the lift shall be marked by this stripe. Color markings shall be distinct and of sufficient size to be clearly visible. 98

12.6.2 *Shapes* — Each structural shape or lift shall be marked with the color designated in 12.6.3 on one cut end or across the rolled face of one flange or leg, adjacent to one cut end. Color markings shall be distinct and of sufficient size to be clearly visible. 98

12.6.3 *Colors* — The following color system shall be used to identify the individual specifications: 98

A 242/A 242M	blue
A 283/A 283M (Grade D)	orange
A 514/A 514M	red
A 529/A 529M	black
A 572/A 572M Grade 42	green and white
A 572/A 572M Grade 50	green and yellow
A 572/A 572M Grade 60	green and gray
A 572/A 572M Grade 65	green and blue
A 588/A 588M	blue and yellow
A 709 Grade 50	green and yellow
A 852/A 852M	blue and orange
A 709 Grade 50W	blue and yellow
A 709 Grade 100	red
A 709 Grade 100W	red and orange
A 709 Grade 70W	blue and orange

12.7 *Heat Treatment Identification:* 98

12.7.1 Material that is eventually required to be heat treated by the material specification, but that is released on the basis of heat-treated test specimens, 98

shall be identified with the letter "G" following the specification designation.

98 **12.7.2** Material that has been given the required full heat treatment by the manufacturer or processor shall be identified with the letters "MT" following the specification designation.

98 **12.8** *Subdivided Material:*

98 **12.8.1** Pieces separated from master material by a supplier shall be identified with the specification number (year-date not required), grade, heat number, and the heat treatment identification, if applicable, along with the trademark, brand, or name of the organization subdividing the material. The identification methods shall be in accordance with the requirement of 12.1 through 12.4, except that the raised letters method for shapes and steel sheet piling is not required. If the original manufacturer's identification remains intact, the material need not be additionally identified by the organization supplying the material.

98 **12.8.2** As an alternative, pieces from the same heat of material may be bundled or placed in secured lifts and the identification specified in 12.8.1 shall then either be placed on the top piece of each lift, or shown on a substantial tag attached to each lift or bundle.

13. Permissible Variations in Dimensions or Weight [Mass]

13.1 One cubic foot of rolled steel is assumed to weigh 490 lb. One cubic metre of rolled steel is assumed to have a mass of 7850 kg.

13.2 *Plates* — The permissible variations for dimensions and weight [mass] shall not exceed the applicable limits in Tables 1 to 15 [Annex A1, Tables A1.1 to A1.15], inclusive.

13.3 *Shapes:*

13.3.1 The permissible variations for dimensions shall not exceed the applicable limits in Tables 16 to 25 [Annex A1, Tables A1.16 to A1.25], inclusive. Permissible variations for special shapes not listed in those tables are subject to negotiation between the manufacturer and the purchaser.

98 NOTE 3—Tolerances are shown in Tables 16 to 25 [Annex A1, Tables A1.16 to A1.25], inclusive, for some shapes that are not listed in Annex A2 (that is, bulb angles, tees, zees). Addition of such sections to Annex A2 will be considered by Subcommittee A01.02 when and if a need for such listing is shown.

13.3.2 *Shapes Having One Dimension of the Cross Section 3 in. [75 mm] or Greater (Structural-Size Shapes)* — The cross-sectional area or weight [mass] of each shape shall not vary more than 2.5% from the theoretical or specified amounts.

13.4 *Sheet Piling* — The weight of each steel sheet pile shall not vary more than 2.5% from the theoretical or specified weight [or mass]. The length of each steel sheet pile shall not vary more than 5 in. [125 mm] over, and shall not be less than the length specified.

13.5 *Bars* — The variations from nominal dimensions of hot-rolled bars shall not exceed the applicable limits in Tables 26 to 31 [Annex A1, Tables A1.26 to A1.31], inclusive.

14. Inspection and Testing

14.1 The inspector representing the purchaser shall have free entry, at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere with the operation of the works.

14.2 When plates are produced from coils, 14.1 shall apply to the processor instead of the manufacturer, and the place of process shall apply instead of the place of manufacture. When plates are produced from coils and the processor is different from the manufacturer, the inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works that concerns the manufacturer of the material ordered.

15. Retests

15.1 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

15.2 If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. [20 mm] from the center of the gage length of a 2 in. [50 mm] specimen or is outside the middle half of the gage length of an 8 in. [200 mm] specimen, as indicated by scribe scratches

marked on the specimen before testing, a retest shall be allowed.

15.3 Except as provided in 15.3.1, if the results from an original tension specimen fails to meet the specified requirements, but are within 2 ksi [14 MPa] of the required tensile strength, within 1 ksi [7 MPa] of the required yield strength or yield point, or within 2 percentage units of the required elongation, a retest shall be permitted to replace the failing test. A retest shall be performed for the failing original test, with the specimen being randomly selected from the heat. If the results of the retest meet the specified requirements, the heat or lot shall be approved.

15.3.1 For plates produced from coils, both tests from each coil tested to qualify a heat must meet all mechanical property requirements. Should either test fail to do so, then that coil cannot be used to qualify the parent heat. However, that portion of that individual coil which is bracketed by acceptable tests (see 11.4.1.3) may be qualified.

15.4 Quenched and tempered steel plates are subject to the additional retest requirements contained in the material specification.

15.5 When the option of 11.3.2 is used and the elongation falls below the specified requirement, another test may be made using a specimen permitted in 11.5.2.

16. Rejection

16.1 Any rejection based on product analysis made in accordance with the material specification shall be reported to the supplier and samples that represent the rejected material shall be preserved for 2 weeks from the date of notification of such rejection. In case of dissatisfaction with the results of the tests, the supplier may make claim for a rehearing within that time.

16.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's or processor's works will be rejected, and the manufacturer or processor shall be notified.

17. Retreatment

17.1 If any heat-treated material fails to meet the mechanical requirements of the applicable specification, the material may be reheat treated. All mechanical property tests shall be repeated and the material surface shall be reexamined for defects when the material is resubmitted for inspection.

18. Test Reports

18.1 Test reports for each heat supplied are required and they shall report the following:

18.1.1 The specification designation, including year date, and the grade or class if applicable, to which the material is furnished.

18.1.2 The heat number, heat analysis, and nominal sizes.

18.1.3 Except as otherwise permitted in 18.1.3.1 and 18.1.3.2, the results of two tension tests from material of thicknesses sufficient to qualify the material shipped.

18.1.3.1 Only one test need be reported when the amount of material from a shipment is less than 10 tons [9 Mg] and the thickness variations described in 11.4 were not exceeded.

18.1.3.2 Only one test need be reported when the shipment consists of a single piece.

18.1.4 When the material is required to be heat treated, either by the designated ASTM specification, or when specified in the purchase order, all heat treatments, including temperature ranges and time at temperature.

18.1.4.1 A heat treat procedure may be supplied in place of the actual temperatures and times when agreed to by the purchaser and the supplier.

18.1.4.2 Subcritical heat treatment to soften thermally cut edges need not be reported except for materials having specified minimum tensile strengths of 95 ksi [655 MPa] or higher, unless such subcritical heating is accomplished at temperatures at least 75°F [40°C] lower than the minimum tempering temperature.

18.2 The thickness of the product tested may not necessarily be the same as an individual ordered thickness since it is the heat that is tested rather than each ordered item. Tests from material thicknesses in accordance with 11.4 and encompassing the thicknesses in a shipment shall be sufficient for qualifying the material in the shipment. These test thicknesses may or may not be within previously tested and shipped thicknesses from the same heat.

18.3 For plates produced from coils, both test results shall be reported for each qualifying coil.

18.4 For plates produced from coils, both the manufacturer and processor shall be identified on the test report.

18.5 When full-section test specimens have been used for the qualification of angles, that information shall be stated on the test report.

18.6 A signature is not required on the test report. However, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

18.7 When finished material is supplied to a purchase order specifying an ASTM material specification listed in the Scope section of Specification A 6/A 6M, the organization supplying that material shall provide the purchaser with a copy of the original manufacturer's test report.

19. Packaging, Marking, and Loading for Shipment

19.1 Packaging, marking, and loading for shipment shall be in accordance with those procedures recommended by Practices A 700.

19.2 When Level A is specified, and when specified in the contract or order, and for direct procurement by or direct shipment to the U. S. government, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

19.3 When specified in the contract or order, and for direct procurement by or direct shipment to the U. S. government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and with Fed. Std. No. 123 for civil agencies.

TABLE A
SHAPE SIZE GROUPINGS FOR TENSILE PROPERTY CLASSIFICATION

Note 1 — SI designations, from Annex A2, are shown in brackets.
Note 2 — Tees cut from W, M, and S shapes fall within the same group as the shape from which they are cut.

Shape Type	Group 1	Group 2	Group 3	Group 4	Group 5
W shapes	W24 × 55 & 62 [W610 × 82 & 92] W21 × 44 to 57 incl [W530 × 66 to 85 incl] W18 × 35 to 71 incl [W460 × 52 to 106 incl] W16 × 26 to 57 incl [W410 × 38.8 to 85 incl] W14 × 22 to 53 incl [W360 × 32.9 to 79 incl] W12 × 14 to 58 incl [W310 × 21.0 to 86 incl] W10 × 12 to 45 incl [W250 × 17.9 to 67 incl] W8 × 10 to 48 incl [W200 × 15.0 to 71 incl] W6 × 9 to 25 incl [W150 × 13.5 to 37.1 incl] W5 × 16 & 19 [W130 × 23.8 & 28.1] W4 × 13 [W100 × 19.3]	W40 × 149 to 268 incl [W1000 × 222 to 399 incl] W36 × 135 to 210 incl [W920 × 201 to 313 incl] W33 × 118 to 152 incl [W840 × 176 to 226 incl] W30 × 90 to 211 incl [W760 × 134 to 314 incl] W27 × 84 to 178 incl [W690 × 125 to 263 incl] W24 × 68 to 162 incl [W610 × 101 to 241 incl] W21 × 62 to 147 incl [W530 × 92 to 219 incl] W18 × 76 to 143 incl [W460 × 113 to 213 incl] W16 × 67 to 100 incl [W410 × 100 to 149 incl] W14 × 61 to 132 incl [W360 × 91 to 196 incl] W12 × 65 to 106 incl [W310 × 97 to 158 incl] W10 × 49 to 112 incl [W250 × 73 to 167 incl] W8 × 58 & 67 [W200 × 86 & 100]	W40 × 277 to 328 incl [W1000 × 412 to 488 incl] W36 × 230 to 300 incl [W920 × 342 to 446 incl] W33 × 201 to 291 incl [W840 × 299 to 433 incl] W30 × 235 to 261 incl [W760 × 350 to 389 incl] W27 × 194 to 258 incl [W690 × 289 to 384 incl] W24 × 176 to 229 incl [W610 × 262 to 341 incl] W21 × 166 to 223 incl [W530 × 248 to 331 incl] W18 × 158 to 192 incl [W460 × 235 to 286 incl] W14 × 145 to 211 incl [W360 × 216 to 314 incl] W12 × 120 to 190 incl [W310 × 179 to 283 incl]	W40 × 362 to 655 incl [W1000 × 539 to 976 incl] W36 × 328 to 798 incl [W920 × 488 to 1188 incl] W33 × 318 to 619 incl [W920 × 473 to 922 incl] W30 × 292 to 581 incl [760 × 434 to 865 incl] W27 × 281 to 539 incl [W690 × 419 to 892 incl] W24 × 250 to 492 incl [W610 × 372 to 732 incl] W21 × 248 to 402 incl [W530 × 370 to 599 incl] W18 × 211 to 311 incl [W460 × 315 to 464 incl] W14 × 233 to 550 incl [W360 × 347 to 818 incl] W12 × 210 to 336 incl [W310 × 313 to 500 incl]	W36 × 920 [W920 × 1369] W14 × 605 to 873 incl [W360 × 900 to 1299 incl]
M Shapes	to 18.9 lb/ft, incl [to 28.1 kg/m, incl]				
S Shapes	to 35 lb/ft, incl [to 52 kg/m, incl]	over 35 lb/ft [over 52 kg/m]			
HP Shapes		to 102 lb/ft, incl [to 152 kg/m, incl]	over 102 lb/ft [over 152 kg/m]		
C Shapes	to 20.7 lb/ft, incl [to 30.8 kg/m, incl]	over 20.7 lb/ft [over 30.8 kg/m]			
MC Shapes	to 28.5 lb/ft, incl [to 42.4 kg/m, incl]	over 28.5 lb/ft [over 42.4 kg/m]			
L Shapes	to ½ in., incl [to 13 mm, incl]	over ½ to ¾ in., incl [over 13 to 19 mm, incl]	over ¾ in. [over 19 mm]		

98

TABLE B
PRODUCT ANALYSIS TOLERANCES

Note — Where "..." appears in this table there is no requirement.

Element	Upper Limit, or Maximum Specified Value, %	Tolerances, %	
		Under Minimum Limit	Over Maximum Limit
Carbon	to 0.15 incl	0.02	0.03
	over 0.15 to 0.40 incl	0.03	0.04
	over 0.40 to 0.75 incl	0.04	0.05
	over 0.75	0.04	0.06
Manganese[A]	to 0.60 incl	0.05	0.06
	over 0.60 to 0.90 incl	0.06	0.08
	over 0.90 to 1.20 incl	0.08	0.10
	over 1.20 to 1.35 incl	0.09	0.11
	over 1.35 to 1.65 incl	0.09	0.12
	over 1.65 to 1.95 incl	0.11	0.14
	over 1.95	0.12	0.16
Phosphorus	to 0.04 incl	...	0.010
	over 0.04 to 0.15 incl	...	NA[B]
Sulfur	to 0.06 incl	...	0.010
	over 0.06	N/A[B]	N/A[B]
Silicon	to 0.30 incl	0.02	0.03
	over 0.30 to 0.40 incl	0.05	0.05
	over 0.40 to 2.20 incl	0.06	0.06
Nickel	to 1.00 incl	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05
	over 2.00 to 3.75 incl	0.07	0.07
	over 3.75 to 5.30 incl	0.08	0.08
	over 5.30	0.10	0.10
Chromium	to 0.90 incl	0.04	0.04
	over 0.90 to 2.00 incl	0.06	0.06
	over 2.00 to 4.00 incl	0.10	0.10
Molybdenum	to 0.20 incl	0.01	0.01
	over 0.20 to 0.40 incl	0.03	0.03
	over 0.40 to 1.15 incl	0.04	0.04
Copper	0.20 minimum only	0.02	...
	to 1.00 incl	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05
Titanium	to 0.10 incl	0.01[C]	0.01[C]
Vanadium	to 0.10 incl	0.01[C]	0.01[C]
	over 0.10 to 0.25 incl	0.02	0.02
	over 0.25	0.02	0.03
	minimum only specified	0.01	...
Boron	any	NA[B]	NA[B]
Columbium	to 0.10 incl	0.01[C]	0.01[C]
Zirconium	to 0.15 incl	0.03	0.03
Nitrogen	to 0.030 incl	0.005	0.005

[A] Manganese product analysis tolerances for bars and bar size shapes shall be: to 0.90 incl ±0.03; over 0.90 to 2.20 incl ±0.06.
[B] NA — Product analysis not applicable.
[C] If the minimum of the range is 0.01%, the under tolerance is 0.005%.

INDEX TO TABLES OF PERMISSIBLE VARIATIONS

Dimension	Table	
	Inch-Pound Units	SI Units
Camber		
Plates, Carbon Steel; Sheared and Gas-Cut	12	A1.12
Plates, Carbon Steel; Universal Mill	11	A1.11
Plates, Other than Carbon Steel; Sheared, Gas-Cut and Universal Mill	11	A1.11
Shapes, Rolled; S, M, C, MC, and L	21	A1.21
Shapes, Rolled; W and HP	24	A1.24
Shapes, Split; L and T	25	A1.25
Cross Section of Shapes and Bars		
Flats	26	A1.26
Hexagons	28	A1.28
Rounds and Squares	27	A1.27
Shapes, Rolled; L, Bulb Angles, and Z	17	A1.17
Shapes, Rolled; W, HP, S, M, C, and MC	16	A1.16
Shapes, Rolled; T	18	A1.18
Shapes, Split; L and T	25	A1.25
Diameter		
Plates, Sheared	6	A1.6
Plates, Other than Alloy Steel, Gas-Cut	7	A1.7
Plates, Alloy Steel, Gas-Cut	10	A1.10
Rounds	27	A1.27
Ends Out-of-Square		
Shapes, Other than W	20	A1.20
Shapes, W	22	A1.22
Shapes, Milled, Other than W	23	A1.23
Flatness		
Plates, Carbon Steel	13	A1.13
Plates, Other than Carbon Steel	14	A1.14
Length		
Bars	30	A1.30
Bars, Recut	31	A1.31
Plates, Sheared and Universal Mill	3	A1.3
Plates, Other than Alloy Steel, Gas-Cut	9	A1.9
Plates, Alloy Steel, Gas-Cut	8	A1.8
Plates, Mill Edge	4	A1.4
Shapes, Rolled; Other than W	19	A1.19
Shapes, Rolled; W and HP	22	A1.22
Shapes, Split; L and T	25	A1.25
Shapes, Milled	23	A1.23
Straightness		
Bars	29	A1.29
Shapes, Other than W	21	A1.21
Sweep		
Shapes, W and HP	24	A1.24
Thickness		
Flats	26	A1.26
Plates, Ordered to Thickness	1	A1.1
Waviness		
Plates	15	A1.15
Weight [Mass]		
Plates, Ordered to Weight [Mass]	2	A1.2
Width		
Flats	26	A1.26
Plates, Sheared	3	A1.3
Plates, Universal Mill	5	A1.5
Plates, Other than Alloy Steel, Gas-Cut	9	A1.9
Plates, Alloy Steel, Gas-Cut	8	A1.8
Plates, Mill Edge	4	A1.4

TABLE 1
PERMISSIBLE VARIATIONS IN THICKNESS FOR RECTANGULAR, CARBON, HIGH-STRENGTH, LOW-ALLOY, AND ALLOY-STEEL PLATES, 15 IN. AND UNDER IN THICKNESS WHEN ORDERED TO THICKNESS

Note 1 — Tables 1 through 31, inclusive, contain permissible variations in dimensions stated in inch-pound units.
Note 2 — Permissible variation under specified thickness, 0.01 in.
Note 3 — Thickness to be measured at 3/8 to 3/4 in. from the longitudinal edge.
Note 4 — For thickness measured at any location other than that specified in Note 3, the permissible maximum over tolerance shall be increased by 75%, rounded to the nearest 0.01 in.
Note 5 — Where "..." appears in this table there is no requirement.

Specified Thickness, in.	Tolerance Over Specified Thickness for Widths Given, in.											
	48 and under	Over 48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 132, excl	132 to 144, excl	144 to 168, excl	168 to 182, excl	182 and over
To 1/4, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	...	...	...
1/4 to 5/16, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	...	...	...
5/16 to 3/8, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	...	...
3/8 to 7/16, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
7/16 to 1/2, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
1/2 to 5/8, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.07	...
5/8 to 3/4, excl	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.07	0.07
3/4 to 1, excl	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.07	0.08	0.09
1 to 2, excl	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.10	0.10	0.11	0.13	0.16
2 to 3, excl	0.09	0.09	0.09	0.10	0.10	0.11	0.12	0.13	0.14	0.15	0.15	...
3 to 4, excl	0.11	0.11	0.11	0.11	0.11	0.13	0.14	0.14	0.14	0.15	0.17	...
4 to 6, excl	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20	0.20	...
6 to 10, excl	0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.27	0.28	...
10 to 12, excl	0.29	0.29	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.35	...
12 to 15, excl	0.29	0.29	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	...

TABLE 2
PERMISSIBLE VARIATIONS IN WEIGHT FOR RECTANGULAR SHEARED PLATES AND UNIVERSAL MILL PLATES 613.0 LB/FT^2 AND UNDER WHEN ORDERED TO WEIGHT

Note 1 — Permissible variations in overweight for lots of circular and sketch plates shall be 1$^1/_4$ times the amounts in this table.
Note 2 — Permissible variations in overweight for single plates shall be 1$^1/_3$ times the amounts in this table.
Note 3 — Permissible variations in overweight for single circular and sketch plates shall be 1$^2/_3$ times the amounts in this table.
Note 4 — The adopted standard density of rolled steel is 490 lb/ft^3.
Note 5 — Where ". . ." appears in this table there is no requirement.

Specified Weights, lb/ft^2	Permissible Variation in Average Weight of Lots[A] for Widths Given in Inches, Expressed in Precentage of the Specified Weight per Square Foot																					
	48 and Under		Over 48 to 60, excl		60 to 72, excl		72 to 84, excl		84 to 96, excl		96 to 108, excl		108 to 120, excl		120 to 132, excl		132 to 144, excl		144 to 168, excl		168 and over	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
To 10, excl	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	9.0	3.0	11.0	3.0	13.0	3.0	. . .	. . .	. . .	. . .
10 to 12.5, excl	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.5	3.0	7.0	3.0	8.0	3.0	9.0	3.0	12.0	3.0	. . .	. . .
12.5 to 15.0, excl	4.0	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	8.0	3.0	11.0	3.0	. . .	. . .
15 to 17.5, excl	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.0	3.0	9.0	3.0	10.0	3.0
17.5 to 20, excl	3.5	2.5	3.5	2.5	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	8.0	3.0	9.0	3.0
20 to 25, excl	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	7.0	3.0	8.0	3.0
25 to 30, excl	3.0	2.5	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	5.0	3.0	6.5	3.0	7.0	3.0
30 to 40, excl	3.0	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.5	3.5	2.5	4.0	3.0	4.5	3.0	6.0	3.0	6.5	3.0
40 to 81.7, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	4.0	3.0	5.5	3.0	6.0	3.0
81.7 to 122.6, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0
122.6 to 163.4, excl	2.5	1.5	2.5	1.5	2.5	1.5	2.5	1.5	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	3.0	2.0	3.5	2.0
163.4 to 245.1, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0	3.5	1.0
245.1 to 409.0, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0
409.0 to 490.1, excl	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0
490.1 to 613.0, excl	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0

[A] The term "lot" means all the plates of each tabular width and weight group represented in each shipment.

TABLE 3
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR SHEARED PLATES 1½ IN. AND UNDER IN THICKNESS; LENGTH ONLY OF UNIVERSAL MILL PLATES 2½ IN. AND UNDER IN THICKNESS

Specified Dimensions, in.		Variations over Specified Width and Length[A] for Thicknesses, in., and Equivalent Weights, lb/ft², Given							
		To 3/8, excl		3/8 to 5/8, excl		5/8 to 1, excl		1 to 2, incl[B]	
		To 15.3, excl		15.3 to 25.5, excl		25.5 to 40.8, excl		40.8 to 81.7, incl	
Length	Width	Width	Length	Width	Length	Width	Length	Width	Length
To 120, excl	To 60, excl	3/8	1/2	7/16	5/8	1/2	3/4	5/8	1
	60 to 84, excl	7/16	5/8	1/2	11/16	5/8	7/8	3/4	1
	84 to 108, excl	1/2	3/4	5/8	7/8	3/4	1	1	1 1/8
	108 and over	5/8	7/8	3/4	1	7/8	1 1/8	1 1/8	1 1/4
120 to 240, excl	To 60, excl	3/8	3/4	1/2	7/8	5/8	1	3/4	1 1/8
	60 to 84, excl	1/2	3/4	5/8	7/8	3/4	1	7/8	1 1/4
	84 to 108, excl	9/16	7/8	11/16	15/16	13/16	1 1/8	1	1 3/8
	108 and over	5/8	1	3/4	1 1/8	7/8	1 1/4	1 1/8	1 3/8
240 to 360, excl	To 60, excl	3/8	1	1/2	1 1/8	5/8	1 1/4	3/4	1 1/2
	60 to 84, excl	1/2	1	5/8	1 1/8	3/4	1 1/4	7/8	1 1/2
	84 to 108, excl	9/16	1	11/16	1 1/8	7/8	1 3/8	1	1 1/2
	108 and over	11/16	1 1/8	7/8	1 1/4	1	1 3/8	1 1/4	1 3/4
360 to 480, excl	To 60, excl	7/16	1 1/8	1/2	1 1/4	5/8	1 3/8	3/4	1 5/8
	60 to 84, excl	1/2	1 1/4	5/8	1 3/8	3/4	1 1/2	7/8	1 5/8
	84 to 108, excl	9/16	1 1/4	3/4	1 3/8	7/8	1 1/2	1	1 7/8
	108 and over	3/4	1 3/8	7/8	1 1/2	1	1 5/8	1 1/4	1 7/8
480 to 600, excl	To 60, excl	7/16	1 1/4	1/2	1 1/2	5/8	1 5/8	3/4	1 7/8
	60 to 84, excl	1/2	1 3/8	5/8	1 1/2	3/4	1 5/8	7/8	1 7/8
	84 to 108, excl	5/8	1 3/8	3/4	1 1/2	7/8	1 5/8	1	1 7/8
	108 and over	3/4	1 1/2	7/8	1 5/8	1	1 3/4	1 1/4	1 7/8
600 to 720, excl	To 60, excl	1/2	1 3/4	5/8	1 7/8	3/4	1 7/8	7/8	2 1/4
	60 to 84, excl	5/8	1 3/4	3/4	1 7/8	7/8	1 7/8	1	2 1/4
	84 to 108, excl	5/8	1 3/4	3/4	1 7/8	7/8	1 7/8	1 1/8	2 1/4
	108 and over	7/8	1 3/4	1	2	1 1/8	2 1/4	1 1/4	2 1/2
700 and over	To 60, excl	9/16	2	3/4	2 1/8	7/8	2 1/4	1	2 3/4
	60 to 84, excl	3/4	2	7/8	2 1/8	1	2 1/4	1 1/8	2 3/4
	84 to 108, excl	3/4	2	7/8	2 1/8	1	2 1/4	1 1/4	2 3/4
	108 and over	1	2	1 1/8	2 3/8	1 1/4	2 1/2	1 3/8	3

[A] Permissible variation under specified width and length, 1/4 in.

[B] Permissible variations in length apply also to Universal Mill plates up to 12 in. in width for thicknesses over 2 to 2½ in., incl, except for alloy steel up to 1¾ in. thick.

TABLE 4
PERMISSIBLE VARIATIONS IN WIDTH FOR MILL EDGE CARBON AND HIGH-STRENGTH, LOW-ALLOY PLATES PRODUCED ON STRIP MILLS
(Applies to Either Plates Produced from Coils or Plates Produced in Discrete Cut Lengths of Flat Product)

Specified Width, in.	Variations over Specified Width, in.[A]
To 14, excl	7/16
14 to 17, excl	1/2
17 to 19, excl	9/16
19 to 21, excl	5/8
21 to 24, excl	11/16
24 to 26, excl	13/16
26 to 28, excl	15/16
28 to 35, excl	1 1/8
35 to 50, excl	1 1/4
50 to 60, excl	1 1/2
60 to 65, excl	1 5/8
65 to 70, excl	1 3/4
70 to 80, excl	1 7/8
80 and over	2

[A] No permissible variation under specified width.

TABLE 5
PERMISSIBLE VARIATIONS IN ROLLED WIDTH FOR UNIVERSAL MILL PLATES 15 IN. AND UNDER IN THICKNESS

	Variations over Specified Width[A] for Thickness, in., or Equivalent Weights, lb/ft^2, Given					
Specified Width, in.	To 3/8, excl To 15.3, excl	3/8 to 5/8, excl 15.3 to 25.5, excl	5/8 to 1, excl 25.5 to 40.8, excl	1 to 2, incl 40.8 to 81.7, incl	Over 2 to 10, incl 81.7 to 409.0, incl	Over 10 to 15, incl 409.0 to 613.0, incl
Over 8 to 20, excl	1/8	1/8	3/16	1/4	3/8	1/2
20 to 36, excl	3/16	1/4	5/16	3/8	7/16	9/16
36 and over	5/16	3/8	7/16	1/2	9/16	5/8

[A] Permissible variation under specified width, 1/8 in.

TABLE 6
PERMISSIBLE VARIATIONS IN DIAMETER FOR SHEARED CIRCULAR PLATES 1 IN. AND UNDER IN THICKNESS

Specified Diameters, in.	Permissible Variations over Specified Diameter for Thicknesses Given, in.[A]		
	To 3/8, excl	3/8 to 5/8, excl	5/8 to 1, incl
To 32,excl	1/4	3/8	1/2
32 to 84, excl	5/16	7/16	9/16
84 to 108, excl	3/8	1/2	5/8
108 to 130, excl	7/16	9/16	11/16
130 and over	1/2	5/8	3/4

[A] No permissible variations under specified diameter.

TABLE 7
PERMISSIBLE VARIATIONS IN DIAMETER FOR GAS-CUT CIRCULAR PLATES
(Not Applicable to Alloy Steel)

Specified Diameter, in.	Variations over Specified Diameter for Thicknesses Given, in.[A]					
	to 1, excl	1 to 2, excl	2 to 4, excl	4 to 6, excl	6 to 8, excl	8 to 15, incl
To 32, excl	3/8	3/8	1/2	1/2	5/8	3/4
32 to 84, excl	3/8	1/2	1/2	5/8	3/4	7/8
84 to 108, excl	1/2	9/16	5/8	3/4	7/8	1
108 to 130, excl	1/2	9/16	11/16	7/8	1	1 1/8
130 and over	5/8	3/4	7/8	1	1 1/8	1 1/4

[A] No permissible variation under specified diameter.

TABLE 8
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR RECTANGULAR PLATES WHEN GAS CUTTING IS SPECIFIED OR REQUIRED
(Applies to Alloy Steel Specifications Only)

Note 1 — These variations may be taken all under or divided over and under, if so specified.

Note 2 — Plates with universal rolled edges will be gas cut to length only.

Specified Thickness, in.	Variations Over for All Specified Widths or Lengths, in.
To 2, excl	3/4
2 to 4, excl	1
4 to 6, excl	1 1/8
6 to 8, excl	1 5/16
8 to 15, incl	1 1/2

TABLE 9
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR RECTANGULAR PLATES WHEN GAS CUTTING IS SPECIFIED OR REQUIRED
(Not Applicable to Alloy Steel)

Note 1 — These variations may be taken all under or divided over adn under, if so specified.

Note 2 — Plates with universal rolled edges will be gas cut to length only.

Specified Thickness, in.	Variations Over for All Specified Widths or Lengths, in.
To 2, excl	1/2
2 to 4, excl	5/8
4 to 6, excl	3/4
6 to 8, excl	7/8
8 to 15, incl	1

TABLE 10
PERMISSIBLE VARIATIONS IN DIAMETER FOR GAS-CUT CIRCULAR PLATES
(Applies to Alloy Steel Specifications Only)

Specified Diameter, in.	Variations over Specified Diameter for Thicknesses Given, in.[A]					
	to 1, excl	1 to 2, excl	2 to 4, excl	4 to 6, excl	6 to 8, excl	8 to 15, incl
To 32, excl	1/2	1/2	3/4	3/4	1	1
32 to 84, excl	1/2	5/8	7/8	1	1 1/8	1 1/4
84 to 108, excl	5/8	3/4	1	1 1/8	1 1/4	1 3/8
108 to 130, excl	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2

[A] No permissible variations under specified diameter.

TABLE 11
PERMISSIBLE CAMBER[A] FOR CARBON, ALLOY, AND HIGH-STRENGTH, LOW-ALLOY UNIVERSAL MILL PLATES AND ALLOY AND HIGH-STRENGTH, LOW-ALLOY SHEARED, SPECIAL-CUT, OR GAS-CUT RECTANGULAR PLATES

Thickness, in.	Specified Weights, lb/ft^2	Widths, in.	Camber Tolerances for Thicknesses and Widths Given
To 2, incl	to 81.7, incl	all	1/8 in. × (no. of feet of length/5)
Over 2 to 15, incl	81.7 to 613.0, incl	to 30, incl	3/16 in. × (no. of feet of length/5)
Over 2 to 15, incl	81.7 to 613.0, incl	over 30	1/4 in. × (no. of feet of length/5)

[A] Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE 12
PERMISSIBLE CAMBER[A] FOR SHEARED PLATES AND GAS-CUT RECTANGULAR PLATES, ALL THICKNESSES
(Applies to Carbon Steel Only)

Maximum permissible camber, in. = 1/8 in. × (number of feet of length/5)

[A] Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE 13
PERMISSIBLE VARIATIONS FROM FLATNESS FOR CARBON STEEL PLATES

Note 1 — When the longer dimension is under 36 in., the permissible variation should not exceed 1/4 in. When the longer dimension is from 36 to 72 in., incl, the permissible variation should not exceed 75% of the tabular amount for the specified width, but in no case less than 1/4 in.

Note 2 — These variations apply to plates which have a specified minimum tensile strength of not more than 60 ksi [415 MPa] or comparable chemical composition or hardness. The limits in the table are increased 50% for plates specified to a higher minimum tensile strength or compatible chemistry or hardness.

Note 3 — This table and these notes cover the permissible variations for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

Note 4 — Where "..." appears in this table there is no requirement.

		Permissible Variations from a Flat Surface for Specified Widths, in.[A,B]										
Specified Thickness, in.	Specified Weight, lb/ft^2	To 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 and Over
To 1/4, excl	To 10.2, excl	9/16	3/4	15/16	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	...	...
1/4 to 3/8, excl	10.2 to 15.3, excl	1/2	5/8	3/4	15/16	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	...	...
3/8 to 1/2, excl	15.3 to 20.4, excl	1/2	9/16	5/8	5/8	3/4	7/8	1	1 1/8	1 1/4	1 7/8	2 1/8
1/2 to 3/4, excl	20.4 to 30.6, excl	7/16	1/2	9/16	5/8	5/8	3/4	1	1	1 1/8	1 1/2	2
3/4 to 1, excl	30.6 to 40.8, excl	7/16	1/2	9/16	5/8	5/8	5/8	3/4	7/8	1	1 3/8	1 3/4
1 to 2, excl	40.8 to 81.7, excl	3/8	1/2	1/2	9/16	9/16	5/8	5/8	5/8	11/16	1 1/8	1 1/2
2 to 4, excl	81.7 to 163.4, excl	5/16	3/8	7/16	1/2	1/2	1/2	1/2	9/16	5/8	7/8	1 1/8
4 to 6, excl	163.4 to 245.1, excl	3/8	7/16	1/2	1/2	9/16	9/16	5/8	3/4	7/8	7/8	1
6 to 8, excl	245.1 to 326.8, excl	7/16	1/2	1/2	5/8	11/16	3/4	7/8	7/8	1	1	1
8 to 10, excl	326.8 to 409.0, excl	1/2	1/2	5/8	11/16	3/4	13/16	7/8	15/16	1	1	1
10 to 12, excl	409.0 to 490.1, excl	1/2	5/8	3/4	13/16	7/8	15/16	1	1	1	1	1
12 to 15, excl	490.1 to 613.0, incl	5/8	3/4	13/16	7/8	15/16	1	1	1	1	1	...

[A] *Flatness Variations for Length* — The longer dimension specified is considered the length, and permissible variations in flatness along the length should not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

[B] *Flatness Variations for Width* — The flatness variations across the width should not exceed the tabular amount for the specified width.

TABLE 14
PERMISSIBLE VARIATIONS FROM FLATNESS FOR HIGH-STRENGTH, LOW-ALLOY, AND ALLOY STEEL PLATES, HOT ROLLED OR THERMALLY TREATED

Note 1 — When the longer dimension is under 36 in., the variation should not exceed 3/8 in. When the larger dimension is from 36 to 72 in., incl, the variation should not exceed 75% of the tabular amount for the specified width.

Note 2 — This table and notes cover the tolerances for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

Note 3 — Where "..." appears in this table there is no requirement.

Specified Thickness, in.	Specified Weight, lb/ft^2	Flatness Tolerances for Specified Widths, in.[A,B]										
		To 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 and Over
To 1/4, excl	To 10.2, excl	13/16	1 1/8	1 3/8	1 7/8	2	2 1/4	2 3/8	2 5/8	2 3/4	...	...
1/4 to 3/8, excl	10.2 to 15.3, excl	3/4	15/16	1 1/8	1 3/8	1 3/4	1 7/8	2	2 1/4	2 3/8	...	...
3/8 to 1/2, excl	15.3 to 20.4, excl	3/4	7/8	15/16	15/16	1 1/8	1 5/16	1 1/2	1 5/8	1 7/8	2 3/4	3 1/8
1/2 to 3/4, excl	20.4 to 30.6, excl	5/8	3/4	13/16	7/8	1	1 1/8	1 1/4	1 3/8	1 5/8	2 1/4	3
3/4 to 1, excl	30.6 to 40.8, excl	5/8	3/4	7/8	7/8	15/16	1	1 1/8	1 5/16	1 1/2	2	2 5/8
1 to 2, excl	40.8 to 81.7, excl	9/16	5/8	3/4	13/16	7/8	15/16	1	1	1	1 5/8	2 1/4
2 to 4, excl	81.7 to 163.4, excl	1/2	9/16	11/16	3/4	3/4	3/4	3/4	7/8	1	1 1/4	1 5/8
4 to 6, excl	163.4 to 245.1, excl	9/16	11/16	3/4	3/4	7/8	7/8	15/16	1 1/8	1 1/4	1 1/4	1 1/2
6 to 8, excl	245.1 to 326.8, excl	5/8	3/4	3/4	15/16	1	1 1/8	1 1/4	1 5/16	1 1/2	1 1/2	1 1/2
8 to 10, excl	326.8 to 409.0, excl	3/4	13/16	15/16	1	1 1/8	1 1/4	1 15/16	1 3/8	1 1/2	1 1/2	1 1/2
10 to 12, excl	409.0 to 490.1, excl	3/4	15/16	1 1/8	1 1/4	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2
12 to 15, incl	490.1 to 613.0, incl	7/8	1	1 3/16	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2

[A] *Flatness Variations for Length* — The longer dimension specified is considered the length, and variations from a flat surface along the length should not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

[B] *Flatness Variations for Width* — The flatness variations across the width should not exceed the tabular amount for the specified width.

TABLE 15
PERMISSIBLE VARIATIONS IN WAVINESS FOR PLATES

Note — Waviness denotes the maximum deviation of the surface of the plate from a plane parallel to the surface of the point of measurement and contiguous to the surface of the plate at each of the two adjacent wave peaks, when the plate is resting on a flat horizontal surface, as measured in an increment of less than 12 ft of length.

The waviness tolerance is a function of the flatness tolerance as obtained from Table 13 or 14 as appropriate.

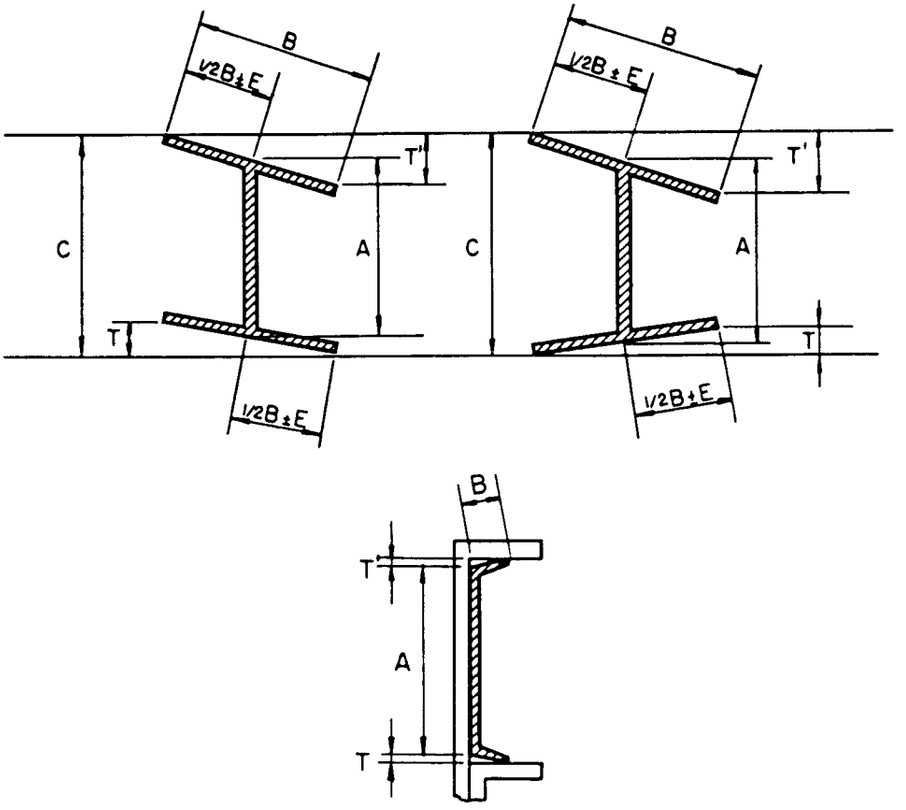
Flatness Tolerance, in., from Tables 13 or 14	Waviness Tolerance, in., When Number of Waves in 12 ft is						
	1	2	3	4	5	6	7
5/16	5/16	1/4	3/16	1/8	1/8	1/16	1/16
3/8	3/8	5/16	3/16	3/16	1/8	1/16	1/16
7/16	7/16	5/16	1/4	3/16	1/8	1/8	1/16
1/2	1/2	3/8	5/16	3/16	3/16	1/8	1/16
9/16	9/16	7/16	5/16	1/4	3/16	1/8	1/8
5/8	5/8	1/2	3/8	1/4	3/16	1/8	1/8
11/16	11/16	1/2	3/8	5/16	3/16	3/16	1/8
3/4	3/4	9/16	7/16	5/16	1/4	3/16	1/8
13/16	13/16	5/8	7/16	5/16	1/4	3/16	1/8
7/8	7/8	11/16	1/2	3/8	1/4	3/16	1/8
15/16	15/16	11/16	1/2	3/8	5/16	1/4	3/16
1	1	3/4	9/16	7/16	5/16	1/4	3/16
1 1/8	1 1/8	7/8	5/8	1/2	3/8	1/4	3/16
1 1/4	1 1/4	15/16	11/16	1/2	3/8	5/16	1/4
1 3/8	1 3/8	1 1/16	3/4	9/16	7/16	5/16	1/4
1 1/2	1 1/2	1 1/8	7/8	5/8	1/2	3/8	1/4
1 5/8	1 5/8	1 1/4	15/16	11/16	1/2	3/8	5/16
1 3/4	1 3/4	1 5/16	1	3/4	9/16	7/16	5/16
1 7/8	1 7/8	1 7/16	1 1/16	13/16	9/16	7/16	5/16
2	2	1 1/2	1 1/8	7/8	5/8	1/2	3/8
2 1/8	2 1/8	1 5/8	1 3/16	7/8	11/16	1/2	3/8
2 1/4	2 1/4	1 11/16	1 1/4	15/16	11/16	9/16	3/8
2 3/8	2 3/8	1 13/16	1 5/16	1	3/4	9/16	7/16
2 1/2	2 1/2	1 7/8	1 7/16	1 1/16	13/16	9/16	7/16
2 5/8	2 5/8	2	1 1/2	1 1/8	13/16	5/8	7/16
2 3/4	2 3/4	2 1/16	1 9/16	1 1/8	7/8	5/8	1/2
2 7/8	2 7/8	2 3/16	1 5/8	1 3/16	15/16	11/16	1/2
3	3	2 1/4	1 11/16	1 1/4	15/16	11/16	9/16
3 1/8	3 1/8	2 3/8	1 3/4	1 5/16	1	3/4	9/16

TABLE 16
PERMISSIBLE VARIATIONS IN CROSS SECTION FOR W, HP, S, M, C, AND MC SHAPES

98

Note 1 — *A* is measured at center line of web for S, M, and W and HP shapes; at back of web for C and MC shapes. Measurement is overall for C shapes under 3 in. *B* is measured parallel to flange. *C* is measured parallel to web.

Note 2 — Where "..." appears in this table there is no requirement.



Shape	Section Nominal Sizes, in.	*A*, Depth, in.		*B*, Flange Width, in.		$T + T'$[A] Flanges Out-of-Square, max, in.[B]	*E*, Web off Center, max, in.[C]	*C*, Maximum Depth at any Cross Section over Theoretical Depth, in.	Thickness of Web Over and Under for Thickness Given, in.	
		Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical				3/16 and Under	Over 3/16
W and HP	Up to 12, incl	1/8	1/8	1/4	3/16	1/4	3/16	1/4	...	...
	Over 12	1/8	1/8	1/4	3/16	5/16	3/16	1/4	...	...
S and M	3 to 7, incl	3/32	1/16	1/8	1/8	1/32	3/16	...	...	...
	Over 7 to 14, incl	1/8	3/32	5/32	5/32	1/32	3/16	...	...	...
	Over 14 to 24, incl	3/16	1/8	3/16	3/16	1/32	3/16	...	...	...
C and MC	1 1/2 and under	1/32	1/32	1/32	1/32	1/32	...	...	0.010	0.015
	Over 1 1/2 to 3, excl	1/16	1/16	1/16	1/16	1/32	...	...	0.015	0.020
	3 to 7, incl	3/32	1/16	1/8	1/8	1/32	...	...	...	...
	Over 7 to 14, incl	1/8	3/32	1/8	5/32	1/32	...	...	...	...
	Over 14	3/16	1/8	1/8	3/16	1/32	...	...	...	...

[A] $T + T'$ applies when flanges of channels are toed in or out. For channels 5/8 in. and under in depth, the permissible out-of-square is 3/64 in./in. of depth.

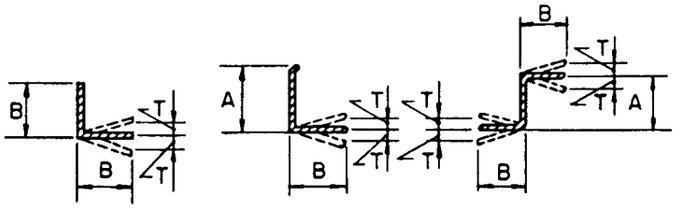
[B] Tolerance is per inch of flange width for S, M, C, and MC shapes.

[C] Variation of 5/16 in. max for sections over 426 lb/ft.

98

TABLE 17
PERMISSIBLE VARIATIONS IN CROSS SECTION FOR ANGLES (L SHAPES), BULB ANGLES, AND ZEES

Note—Where "..." appears in this table there is no requirement.



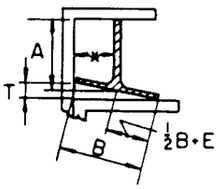
Section	Nominal Size, in.	*A*, Depth, in.		*B*, Flange Width or Length of Leg, in.		*T*, Out of Square per Inch of *B*, in.	Variations from Thickness for Thicknesses Given, Over and Under, in.		
		Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical		$\frac{3}{16}$ and under	Over $\frac{3}{16}$ to $\frac{3}{8}$, incl	Over $\frac{3}{8}$
Angles[A] (L Shapes)	1 and under	...	...	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{3}{128}$[B]	0.008	0.010	...
	Over 1 to 2, incl	...	...	$\frac{3}{64}$	$\frac{3}{64}$	$\frac{3}{128}$[B]	0.010	0.010	0.012
	Over 2 to 3, excl	...	...	$\frac{1}{16}$	$\frac{1}{16}$	$\frac{3}{128}$[B]	0.012	0.015	0.015
	3 to 4, incl	...	...	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{3}{128}$[B]	...	...	...
	Over 4 to 6, incl	...	...	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{128}$[B]	...	...	...
	Over 6	...	...	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{128}$[B]	...	...	...
Bulb angles	(Depth) 3 to 4, incl	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{3}{128}$[B]	...	...	...
	Over 4 to 6, incl	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{128}$[B]	...	...	...
	Over 6	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{128}$[B]	...	...	...
Zees	3 to 4, incl	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{3}{128}$[B]	...	...	...
	Over 4 to 6, incl	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{128}$[B]	...	...	...

[A] For unequal leg angles, longer leg determines classification.
[B] $\frac{3}{128}$ in./in. = $1\frac{1}{2}°$.

TABLE 18
PERMISSIBLE VARIATIONS IN SECTIONAL DIMENSIONS FOR ROLLED TEES

98

Note 1 — * = Back of square and center line of stem are to be parallel when measuring "out-of-square."
Note 2 — Where ". . ." appears in this table there is no requirement.



Tees

	A, Depth,[B] in.		*B,* Width,[B] in.		*T,* Out-of-Square per inch of *B,* in.	*E,* Web-off-Center max, in.	Stem Out-of-Square,[C] in.	Thickness of Flange, in.		Thickness of Stem, in.	
Nominal Size,[A] in.	Over	Under	Over	Under				Over	Under	Over	Under
1¼ and under	3/64	3/64	3/64	3/64	. . .	. . .	1/32	0.010	0.010	0.005	0.020
Over 1¼ to 2, incl	1/16	1/16	1/16	1/16	. . .	. . .	1/16	0.012	0.012	0.010	0.020
Over 2 to 3, excl	3/32	3/32	3/32	3/32	. . .	. . .	3/32	0.015	0.015	0.015	0.020
3 to 5, incl	3/32	1/16	1/8	1/8	1/32	3/32	. . .	. . .	. . .	. . .	. . .
Over 5 to 7, incl	3/32	1/16	1/8	1/8	1/32	1/8	. . .	. . .	. . .	. . .	. . .

[A] The longer member of an unequal tee determines the size for permissible variations.
[B] Measurements for both depth and width are overall.
[C] Stem-out-of-square is the variation from its true position of the center line of stem, measured at the point.

98

TABLE 19
PERMISSIBLE VARIATIONS IN LENGTH FOR S, M, C, MC, L, T, Z, AND BULB ANGLE SHAPES

Note — Where "..." appears in this table there is no requirement.

Nominal Size,[A] in.	Variations from Specified Length for Lengths Given, in.													
	5 to 10 ft, excl		10 to 20 ft, excl		20 to 30 ft, incl		Over 30 to 40 ft, incl		Over 40 to 50 ft, incl		Over 50 to 65 ft, incl		Over 65 ft	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 3	5/8	0	1	0	1 1/2	0	2	0	2 1/2	0	2 1/2	0	...	...
3 and over	1/2	1/4	1/2	1/4	1/2	1/4	3/4	1/4	1	1/4	1 1/8	1/4	1 1/4	1/4

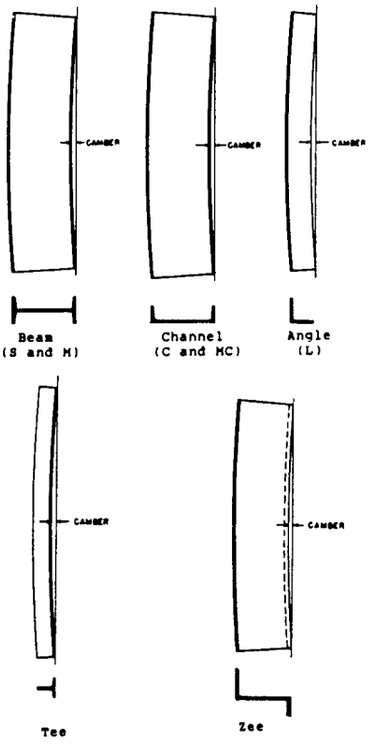
[A] Greatest cross-sectional dimension.

TABLE 20
PERMISSIBLE VARIATIONS IN ENDS OUT-OF-SQUARE FOR S, M, C, MC, L, T, Z, AND BULB ANGLE SHAPES

Shapes	Permissible Variations
S, M, C, and MC	1/64 in./in. of depth
L[A]	3/128 in./in. of leg length or 1 1/2°
Bulb angles	3/128 in./in. of depth or 1 1/2°
Rolled Tees[A]	1/64 in./in. of flange or stem
Zees	3/128 in./in. of sum of both flange lengths

[A] Permissible variations for ends out-of-square are determined on the longer members of the shape.

TABLE 21
PERMISSIBLE VARIATIONS IN STRAIGHTNESS FOR S, M, C, MC, L, T, Z, AND BULB ANGLE SHAPES



Positions for Measuring Camber of Shapes

Variable	Nominal Size,[A] in.	Permissible Variation, in.
Camber	under 3	$\frac{1}{4}$ in. in any 5 ft, or $\frac{1}{4}$ × (number of feet of total length/5)
	3 and over	$\frac{1}{8}$ × (number of feet of total length/5)
Sweep	all	Due to the extreme variations in flexibility of these shapes, straightness tolerances for sweep are subject to negotiations between the manufacturer and the purchaser for the individual sections involved.

[A] Greatest cross-sectional dimension.

TABLE 22
PERMISSIBLE VARIATIONS IN LENGTH FOR W AND HP SHAPES[A,B]

	Variations from Specified Length for Lengths Given, in.			
	30 ft and Under		Over 30 ft	
W and HP Shapes	Over	Under	Over	Under
Beams 24 in. and under in nominal depth	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$ plus $\frac{1}{16}$ for each additional 5 ft or fraction thereof	$\frac{3}{8}$
Beams over 24 in. in nominal depth and all columns	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$ plus $\frac{1}{16}$ for each additional 5 ft or fraction thereof	$\frac{1}{2}$

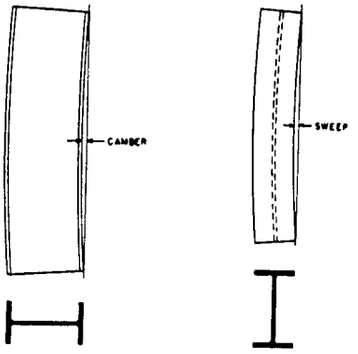
[A] For HP shapes or W shapes when used as bearing piles, the length tolerance is plus 5 in. and minus 0 in. This length tolerance also applies to steel sheet piles.
[B] The ends out-of-square tolerance for W and HP shapes shall be $\frac{1}{64}$ in./in. of depth, or of flange width if it is greater than the depth.

TABLE 23
PERMISSIBLE VARIATIONS FOR LENGTH AND ENDS OUT-OF-SQUARE, MILLED SHAPES

		Milled Both Ends[A]			Milled One-End[A]		
		Length, in.			Length, in.		
Nominal, Depth, in.	Length, ft[B,C]	Over	Under	Maximum End Out-of-Square, in.	Over	Under	Maximum End Out-of-Square, for Milled End, in.
6 to 36	6 to 70	1/32	1/32	1/32	1/4	1/4	1/32

[A] Ends out-of-square are measured by *(a)* squaring from the center line of the web and *(b)* squaring from the center line of the flange. The measured variation from true squareness in either plane may not exceed the total tabular amount.
[B] Length is measured along center line of web. Measurements are made with the steel and tape at the same temperature.
[C] Length variation and out-of-square variation are additive.

TABLE 24
PERMISSIBLE VARIATIONS IN STRAIGHTNESS FOR W AND HP SHAPES



Positions for Measuring Camber and Sweep of W and HP Shapes

	Permissible Variation
Camber and sweep	1/8 in. × (number of feet of total length[A]/10)
When certain sections[B] with a flange width approximately equal to depth are specified, order as columns:	
Lengths of 45 ft and under	1/8 in. × (number of feet of total length/10) but not over 3/8 in.
Lengths over 45 ft	3/8 in. + [1/8 in. × ([number of feet of total length — 45]/10)]

[A] Sections with a flange width less than 6 in., tolerance for sweep = 1/8 in. × (number of feet of total length/5).
[B] Applies only to:
8-in. deep sections 31 lb/ft and heavier,
10-in. deep sections 49 lb/ft and heavier,
12-in. deep sections 65 lb/ft and heavier, and
14-in. deep sections 90 lb/ft and heavier.
If other sections are specified on the order as columns, the tolerance will be subject to negotiation with the manufacturer.

TABLE 25
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR SPLIT TEES AND SPLIT ANGLES (L SHAPES)[A]

Specified Depth, in.	Variations from Depth,[B] Over and Under, in.
To 6, excl (beams and channels)	1/8
6 to 16, excl (beams and channels)	3/16
16 to 20, excl (beams and channels)	1/4
20 to 24, excl (beams)	5/16
24 and over (beams)	3/8

[A] The length tolerance for split tees or angles are the same as those applicable to the section from which the tees or angles are split.

[B] The above tolerances for depth of tees or angles include the allowable tolerances in depth for the beams or channels before splitting. Tolerances both for dimensions and straightness, as set up for the beams or channels from which these tees or angles are cut will apply, except: straightness = 1/8 in. × (length in feet/5).

TABLE 26 98
PERMISSIBLE VARIATIONS IN SECTIONAL DIMENSIONS FOR SQUARE EDGE AND ROUND EDGE FLAT BARS

Note — Where "..." appears in this table there is no requirement.

	Variations from Thickness, for Thicknesses Given Over and Under, in.							Variations from Width, in.	
Specified Widths, in.	0.203 to 0.230, excl	0.203 to 1/4, excl	1/4 to 1/2 incl	Over 1/2 to 1, incl	Over 1 to 2, incl	Over 2 to 3 incl	Over 3	Over	Under
To 1, incl	0.007	0.007	0.008	0.010	...	...	...	1/64	1/64
Over 1 to 2, incl	0.007	0.007	0.012	0.015	1/32	...	...	1/32	1/32
Over 2 to 4, incl	0.008	0.008	0.015	0.020	1/32	3/64	3/64	1/16	1/32
Over 4 to 6, incl	0.009	0.009	0.015	0.020	1/32	3/64	3/64	3/32	1/16
Over 6 to 8, incl	[A]	0.015	0.016	0.025	1/32	3/64	1/16	1/8[B]	3/32[B]

[A] Flats over 6 to 8 in., incl, in width are not available as hot-rolled carbon steel bars in thickness under 0.230 in.

[B] For flats over 6 to 8 in., in width, and 3 in. incl in thickness.

TABLE 27
PERMISSIBLE VARIATIONS IN SECTIONAL DIMENSIONS FOR ROUND AND SQUARE BARS AND ROUND-CORNERED SQUARES

Specified Size, in.	Variations from Size, in.		Out-of-Round or Out-of-Square, in.[A]
	Over	Under	
To 5/16	0.005	0.005	0.008
Over 5/16 to 7/16, incl	0.006	0.006	0.009
Over 7/16 to 5/8, incl	0.007	0.007	0.010
Over 5/8 to 7/8, incl	0.008	0.008	0.012
Over 7/8 to 1, incl	0.009	0.009	0.013
Over 1 to 1 1/8, incl	0.010	0.010	0.015
Over 1 1/8 to 1 1/4, incl	0.011	0.011	0.016
Over 1 1/4 to 1 3/8, incl	0.012	0.012	0.018
Over 1 3/8 to 1 1/2, incl	0.014	0.014	0.021
Over 1 1/2 to 2, incl	1/64	1/64	0.023
Over 2 to 2 1/2, incl	1/32	0	0.023
Over 2 1/2 to 3 1/2, incl	3/64	0	0.035
Over 3 1/2 to 4 1/2, incl	1/16	0	0.046
Over 4 1/2 to 5 1/2, incl	5/64	0	0.058
Over 5 1/2 to 6 1/2, incl	1/8	0	0.070
Over 6 1/2 to 8 1/4, incl	5/32	0	0.085
Over 8 1/4 to 9 1/2, incl	3/16	0	0.100
Over 9 1/2 to 10, incl	1/4	0	0.120

[A] Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same transverse cross section. Out-of-square section is the difference in perpendicular distance between opposite faces, measured at the same transverse cross section.

TABLE 28
PERMISSIBLE VARIATIONS IN SECTIONAL DIMENSIONS FOR HEXAGONS

Specified Sizes Between Opposite Sides, in.	Variations from Size, in.		Maximum Difference, Three Measurements, in.[A]
	Over	Under	
1/2 and under	0.007	0.007	0.011
Over 1/2 to 1, incl	0.010	0.010	0.015
Over 1 to 1 1/2, incl	0.021	0.013	0.025
Over 1 1/2 to 2, incl	1/32	1/64	1/32
Over 2 to 2 1/2, incl	3/64	1/64	3/64
Over 2 1/2 to 3 1/2, incl	1/16	1/64	1/16

[A] Out-of-hexagon section is the greatest difference in distance between any two opposite faces measured at the same transverse cross section.

TABLE 29
PERMISSIBLE VARIATIONS IN STRAIGHTNESS FOR BARS

Maximum Permissible Variations in Straightness, in.[A]
1/4 in any 5 ft, or 1/4 × (number of feet of total length/5)

[A] Permissible variations in straightness do not apply to hot-rolled bars if any subsequent heating operation has been performed.

TABLE 30
PERMISSIBLE VARIATIONS IN LENGTH FOR HOT-CUT STEEL BARS[A]

98

Note — Where "..." appears in this table there is no requirement.

Specified Sizes of Rounds, Squares, and Hexagons, in.	Specified Sizes of Flats, in.		Permissible Variations Over Specified Length Given in Feet, in. (No Variation Under)				
	Thickness	Width	5 to 10 ft. excl	10 to 20 ft. excl	20 to 30 ft. excl	30 to 40 ft. excl	40 to 60 ft. incl
To 1, incl	To 1, incl	To 3, incl	1/2	3/4	1 1/4	1 3/4	2 1/4
Over 1 to 2, incl	Over 1	To 3, incl	5/8	1	1 1/2	2	2 1/2
Over 1 to 2, incl	To 1, incl	Over 3 to 6, incl	5/8	1	1 1/2	2	2 1/2
Over 2 to 5, incl	Over 1	Over 3 to 6, incl	1	1 1/2	1 3/4	2 1/4	2 3/4
Over 5 to 10, incl	...	...	2	2 1/2	2 3/4	3	3 1/4
	0.230 to 1, incl	Over 6 to 8, incl	3/4	1 1/4	1 3/4	3 1/2	4
	Over 1 to 3, incl	Over 6 to 8, incl	1 1/4	1 3/4	2	3 1/2	4
			Hot Sawing				
2 to 5, incl[B]	1 and over	3 and over	[B]	1 1/2	1 3/4	2 1/4	2 3/4
Over 5 to 10, incl	...	...	[B]	2 1/2	2 3/4	3	3 1/4

[A] For flats over 6 to 8 in., incl, in width and over 3 in. in thickness, consult the producer for length tolerances.
[B] Smaller sizes and shorter lengths are not commonly hot sawed.

TABLE 31
PERMISSIBLE VARIATIONS IN LENGTH FOR BARS RECUT BOTH ENDS AFTER STRAIGHTENING[A,B]

Sizes of Rounds, Squares, Hexagons, Width of Flats and Maximum Dimension of Other Sections, in.	Permissible Variations for Specified Length, in.			
	To 12 ft, incl		Over 12 ft	
	Over	Under	Over	Under
To 3, incl	3/16	1/16	1/4	1/16
Over 3 to 6, incl	1/4	1/16	3/8	1/16
Over 6 to 8, incl	3/8	1/16	1/2	1/16
Rounds over 8 to 10, incl	1/2	1/16	5/8	1/16

[A] For flats over 6 to 8 in., incl, in width, and over 3 in. in thickness, consult the producer for length tolerances.
[B] Variations are sometimes required all over or all under the specified length, in which case the sum of the two tolerances applies.

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser. Those that are considered suitable for use with each material specification are listed in the specification. Other tests may be performed by agreement between the supplier and the purchaser. These additional requirements shall apply only when specified in the order, in which event the specified tests shall be made by the manufacturer or processor before shipment of the material.

S1. Vacuum Treatment

S1.1 The steel shall be made by a process which includes vacuum degassing while molten. Unless otherwise agreed upon with the purchaser, it is the responsibility of the manufacturer to select suitable process procedures.

S2. Product Analysis

S2.1 Product analyses shall be made for those elements listed in the material specification. Test frequency shall be as specified on the order. Specimens for analysis shall be taken adjacent to or from the tension test specimen, or from a sample taken from the same relative location as that from which the tension test specimen was taken.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S3.1 The test specimens representing the material shall be thermally treated to simulate heat treatments below the critical temperature which the material may receive during fabrication after heat treatment for mechanical properties. The temperature range, time, and cooling rates shall be as specified in the order.

S4. Additional Tension Test

S4.1 *Plate* — One tension test shall be made from each unit plate rolled from a slab or directly from an ingot, except that for quenched and tempered plates, a test shall be taken from each unit plate heat treated. The results obtained shall be reported on the mill test reports when such tests are required by the order.

S5. Charpy V-Notch Impact Test

S5.1 Charpy V-notch impact tests shall be conducted in accordance with Specification A 673/A 673M.

S5.2 The frequency of testing, the test temperature to be used, and the absorbed energy requirements shall be as specified on the order.

S6. Drop-Weight Test (for Material 0.625 in. [16 mm] and over in Thickness)

S6.1 Drop-weight tests shall be made in accordance with Method E 208. The specimens shall represent the material in the final condition of heat treatment. Agreement shall be reached between the purchaser and the manufacturer or processor as to the number of pieces to be tested and whether a maximum nil-ductility transition (NDT) temperature is mandatory or if the test results are for information only.

S8. Ultrasonic Examination

S8.1 The material shall be ultrasonically examined in accordance with the requirements specified on the order.

S14. Bend Test

S14.1 Bend tests shall be performed with material in the condition prescribed by the material specification. The frequency of testing shall be the same as that specified for tension testing. The bend test specimens shall be taken from the same relative location as the tension test specimen. The longitudinal axis of the specimen shall be parallel to the final direction of rolling.

S14.1.1 Except as provided below, bend test specimens for flats, plates, and shapes shall be at least $1\frac{1}{4}$ in. [30 mm] in width, with both edges parallel through-

out the section in which bending occurs, and may be machined, sheared, or gas cut.

S14.1.2 Bend test specimens for plates over $\frac{3}{4}$ in. [20 mm] in thickness and with a specified minimum tensile strength exceeding 90 ksi [620 MPa], and for other material over $1\frac{1}{2}$ in. [40 mm] in thickness or diameter, except bars to be used for pins and rollers, may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. [20 mm] or to a 1 by $\frac{1}{2}$ in. [25 by 12.5 mm] section. When the test is made on a specimen of reduced thickness, the rolled surface shall be on the outer curve of the bend.

S14.1.3 Bend test specimens for bars to be used for pins and rollers shall be 1 by $\frac{1}{2}$ in. [25 by 12.5 mm] in cross section.

S14.1.4 The sides of the bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in. [1.5 mm] for specimens 2 in. [50 mm] and under in thickness, and not over $\frac{1}{8}$ in. [3 mm] for specimens over 2 in. [50 mm] in thickness.

S14.2 The bend test specimens shall withstand being bent cold through 180°, without cracking on the outside of the bent portion, to an inside diameter that shall have a relation to the thickness of the specimen as prescribed in Table S1.1 for the material specification. Bend diameters for materials not listed in Table S1.1 shall be specified in the order.

S14.3 If a bend specimen fails due to conditions of bending more severe than required by the specification, a retest shall be permitted, either on a duplicate specimen or on a remaining portion of the failed specimen.

S14.4 If a sheared or gas-cut bend test specimen fails due to conditions associated with the sheared or gas-cut edges, a retest shall be permitted on a duplicate machined specimen.

S15. Reduction of Area Measurement

S15.1 The reduction of area, as determined on the 0.500 in. [12.5 mm] diameter round tension test specimen in accordance with Test Methods and Definitions A 370, shall not be less than 40%.

S18. Maximum Tensile Strength

S18.1 Steel having a specified minimum tensile strength of less than 70 ksi [485 MPa] shall not exceed the minimum specified tensile strength by more than 30 ksi [205 MPa].

S18.2 Steel having a minimum specified tensile strength of 70 ksi [485 MPa] or higher shall not exceed the minimum specified tensile strength by more than 25 ksi [170 MPa].

S23. Copper-Bearing Steel (for improved atmospheric corrosion resistance)

S23.1 The copper content shall be a minimum of 0.20% on heat analysis, 0.18 on product analysis.

S26. Subdivided Material — Marking of Individual Pieces

S26.1 Subdivided pieces shall be individually identified by marking, stenciling, or die stamping the specification number (year-date not required), grade, heat number, and the heat treatment identification, if applicable, along with the trademark, brand, or name of the organization subdividing the material. As an alternative, a code traceable to the original required identification may be used to identify individual subdivided pieces, provided the trademark name or brand of the organization subdividing the material is also placed on the material and the original required identification, cross referenced on the code, is furnished with the material.

S74. Maximum Carbon Equivalent for Weldability

S74.1 Plates and shapes shall be supplied with a specific maximum carbon equivalent value as specified by the purchaser. This value shall be based on heat analysis. The required chemical analysis as well as the carbon equivalent shall be reported.

S74.2 The carbon equivalent shall be calculated using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S74.3 For additional information on the weldability of steel, see Appendix X3.

TABLE S1.1
BEND TEST REQUIREMENTS

Specification	Grade	Ratio of Bend Diameter to Specimen Thickness[A] — Material Thickness, in. [mm]						
		3/4 and under [20 and under]	Over 3/4 to 1, incl [Over 20 to 25, incl]	Over 1 to 1 1/2, incl [Over 25 to 40, incl]	Over 1 1/2 to 2, incl [Over 40 to 50, incl]	Over 2 to 3, incl [Over 50 to 75, incl]	Over 3 to 4, incl [Over 75 to 100, incl]	Over 4 [Over 100, incl]
A 36/A 36M	[B]	1/2	1	1 1/2	2 1/2	3	3	3
A 242	[B]	1	1 1/2	2	2 1/2	3	3	[C]
A 283/A 283M	A	flat	flat	1/2	1	1 1/2	2	2 1/2
	B	flat	flat	3/4	1 1/2	2	2 1/2	3
	C	flat	1/2	1	2	2 1/2	3	3 1/2
	D	1/2	1	1 1/2	2 1/2	3	3 1/2	4
A 284	A	flat	flat	1/2	1	1 1/2	2	2 1/2
	B	flat	1/2	1	1 1/2	2	2 1/2	3
	C	1/2	1	1 1/2	2	2 1/2	3	3 1/2
	D	1/2	1	1 1/2	2 1/2	3	3 1/2	4
A 328	[B]	2	[C]	[C]	[C]	[C]	[C]	[C]
A 514	all	2	2	3	3	4	4	[C]
A 529	42	1	[C]	[C]	[C]	[C]	[C]	[C]
	50	1	1 1/2	2 1/2	[C]	[C]	[C]	[C]
A 572	42	1	1 1/2	2	2 1/2	3	3	4[D]
	50	1	1 1/2	2 1/2	3[E]	3 1/2	4	[C]
	60	2	2 1/2	3	[C]	[C]	[C]	[C]
	65	2 1/2[F]	3	3 1/2	[C]	[C]	[C]	[C]
A 573	65	1 1/2	1 1/2	2	[C]	[C]	[C]	[C]
	70	2	2	2	[C]	[C]	[C]	[C]
A 588	all	1	1 1/2	2	2 1/2	3	3	3[G]
A 633	all	2	2	2 1/2	2 1/2	3	3	3
A 656	50	[H]	[C]	[C]	[C]	[C]	[C]	[C]
	60	[I]	[C]	[C]	[C]	[C]	[C]	[C]
	70	[J]	[C]	[C]	[C]	[C]	[C]	[C]
	80	[K]	[C]	[C]	[C]	[C]	[C]	[C]
A 678	A	1	2	2	[C]	[C]	[C]	[C]
	B	2	2	2	2 1/2	2 1/2[L]	[C]	[C]
	C	2	3	3	3	[C]	[C]	[C]
A 690	[B]	2	2	[C]	[C]	[C]	[C]	[C]
A 709	36	1/2	1	1 1/2	2 1/2	3	3	3
	50	1	1 1/2	2 1/2	3[C]	3 1/2	4	[C]
	50W	1	1 1/2	2	2 1/2	3	3	3[G]
	100	2	2	3	3	4	4	[C]
	100W	2	2	3	3	4	4	[C]
A 710	all	2	2	[C]	[C]	[C]	[C]	[C]
A 808/A 808M	[B]	1	1 1/2	2	2 1/2	3	[C]	[C]

[A] The above ratios apply to the bending performance of a test specimen only. This specimen is always taken in the longitudinal direction and usually has some edge preparation. Where plates are to be bent in a fabricating operation more liberal bend radii must be used, particularly if this bend axis is in the unfavorable (longitudinal) direction.

[B] The standard contains only one grade.

[C] The size and grade is not described in this specification.

[D] Over 4 to 6 in. [100 to 150 mm], incl.

[E] Applicable to webs of structural shapes.

[F] 1/2 in. [12.5 mm] max specimen thickness.

[G] Over 4 to 8 in. [100 to 200 mm], incl.

[H] To 1/4 in. [6 mm]: 1/2; over 1/4 to 5/8 in. [6 to 16 mm]: 1.

[I] To 1/4 in. [6 mm]: 1; over 1/4 to 5/8 in. [6 to 16 mm]: 1 1/2.

[J] To 1/4 in. [6 mm]: 1 1/2; over 1/4 to 5/8 in. [6 to 16 mm]: 2.

[K] To 1/4 in. [6 mm]: 2; over 1/4 to 5/8 in. [6 to 16 mm]: 2 1/2.

[L] Over 2 to 2 1/2 [50 to 65 mm] incl.

ANNEXES

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS AND MASS IN SI UNITS

A1.1 Listed in Tables A1.1 through A1.31 are permissible variations in dimensions and mass expressed in the International System of Units (SI) terminology.

TABLE A1.1 98

PERMISSIBLE VARIATIONS IN THICKNESS FOR RECTANGULAR CARBON, HIGH-STRENGTH LOW-ALLOY, AND ALLOY STEEL PLATES, 300 MM AND UNDER IN THICKNESS WHEN ORDERED TO THICKNESS

Note 1 — Permissible variation under specified thickness, 0.3 mm.
Note 2 — Thickness to be measured at 10 to 20 mm from the longitudinal edge.
Note 3 — For specified thicknesses other than those shown, the next higher thickness will apply.
Note 4 — For thickness measured at any location other than that specified in Note 2, the permissible maximum over tolerance shall be increased by 75%, rounded to the nearest 0.1 mm.
Note 5 — Where "..." appears in this table there is no requirement.

	Tolerance Over Specified Thickness for Widths Given in Millimetres, mm										
Specified Thickness, mm	1200 and Under	Over 1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, excl	3000 to 3300, excl	3300 to 3600, excl	3600 to 4200, excl	4200 and Over
5.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	...	...
5.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	...	...
6.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.1	...	...
7.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.4	...
8.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.4	...
9.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	...
10.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.7
11.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.7
12.0	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.0	1.3	1.5	1.8
14.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.5	1.8
16.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.5	1.8
18.0	0.8	0.8	0.8	0.8	0.9	1.0	1.1	1.2	1.4	1.6	2.0
20.0	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.2	1.4	1.6	2.0
22.0	0.8	0.9	0.9	0.9	1.0	1.1	1.3	1.3	1.5	1.8	2.0
25.0	0.9	0.9	1.0	1.0	1.0	1.2	1.3	1.5	1.5	1.8	2.2
28.0	1.0	1.0	1.1	1.1	1.1	1.3	1.4	1.8	1.8	2.0	2.2
30.0	1.1	1.1	1.2	1.2	1.2	1.4	1.5	1.8	1.8	2.1	2.4
32.0	1.2	1.2	1.3	1.3	1.3	1.5	1.6	2.0	2.0	2.3	2.6
35.0	1.3	1.3	1.4	1.4	1.4	1.6	1.7	2.3	2.3	2.5	2.8
38.0	1.4	1.4	1.5	1.5	1.5	1.7	1.8	2.3	2.3	2.7	3.0
40.0	1.5	1.5	1.6	1.6	1.6	1.8	2.0	2.5	2.5	2.8	3.3
45.0	1.6	1.6	1.7	1.8	1.8	2.0	2.3	2.8	2.8	3.0	3.5
50.0	1.8	1.8	1.8	2.0	2.0	2.3	2.5	3.0	3.0	3.3	3.8
55.0	2.0	2.0	2.0	2.2	2.2	2.5	2.8	3.3	3.3	3.5	3.8
60.0	2.3	2.3	2.3	2.4	2.4	2.8	3.0	3.4	3.4	3.8	4.0
70.0	2.5	2.5	2.5	2.6	2.6	3.0	3.3	3.5	3.6	4.0	4.0
80.0	2.8	2.8	2.8	2.8	2.8	3.3	3.5	3.5	3.6	4.0	4.0
90.0	3.0	3.0	3.0	3.0	3.0	3.5	3.5	3.5	3.6	4.0	4.4
100.0	3.3	3.3	3.3	3.3	3.5	3.8	3.8	3.8	3.8	4.4	4.4
110.0	3.5	3.5	3.5	3.5	3.5	3.8	3.8	3.8	3.8	4.4	4.4
120.0	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	4.8	4.8
130.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5.2	5.2
140.0	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	5.6	5.6
150.0	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	5.6	5.6
160.0	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	5.6	5.6
180.0	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	6.3	6.3
200.0	5.8	5.8	6.0	6.0	6.0	6.0	6.0	6.0	6.0	7.0	7.0
250.0	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	8.8
300.0	7.5	7.5	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0

TABLE A1.2
PERMISSIBLE VARIATIONS IN MASS FOR RECTANGULAR SHEARED PLATES AND UNIVERSAL MILL PLATES 2983 kg/m^2 AND UNDER WHEN ORDERED TO MASS

Note 1 — Permissible variations in excess mass for lots of circular and sketch plates shall be 1¼ times the amounts in this table.
Note 2 — Permissible variations in excess mass for single plates shall be 1⅓ times the amounts in this table.
Note 3 — Permissible variations in excess mass for single circular and sketch plates shall be 1⅔ times the amounts in this table.
Note 4 — The adopted standard density for rolled steel is 7850 kg/m^3.
Note 5 — Where "..." appears in this table there is no requirement.

Specified Mass, kg/m^2	Permissible Variation in Average Mass of Lots[A] for Widths Given in Millimetres, Expressed in Precentage of the Specified Masses per Square Metre																					
	1200 and Under		Over 1200 to 1500, excl		1500 to 1800, excl		1800 to 2100, excl		2100 to 2400, excl		2400 to 2700, excl		2700 to 3000, excl		3000 to 3300, excl		3300 to 3600, excl		3600 to 4200, excl		4200 and Over	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
To 51.02, excl	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.5	3.0	9.0	3.0	...	...	...	...	...	...	...	...
51.02 to 62.80, excl	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	6.5	3.0	7.0	3.0	8.0	3.0	9.0	3.0	...	...	...	...
62.80 to 74.58, excl	4.0	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	5.5	3.0	6.0	3.0	7.5	3.0	8.0	3.0	11	3.0	...	...
74.58 to 86.35, excl	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.0	3.0	5.5	3.0	6.0	3.0	7.0	3.0	9.0	3.0	10	3.0
86.35 to 102.0, excl	3.5	2.5	3.5	2.5	3.5	3.0	4.0	3.0	4.5	3.0	4.5	3.0	5.0	3.0	5.5	3.0	6.0	3.0	8.0	3.0	9.0	3.0
102.0 to 125.6, excl	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.0	3.0	4.5	3.0	5.0	3.0	5.5	3.0	7.0	3.0	8.0	3.0
125.6 to 149.2, excl	3.0	2.5	3.5	2.5	3.5	2.5	3.5	3.0	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0	5.0	3.0	6.5	3.0	7.0	3.0
149.2 to 196.2, excl	3.0	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.5	3.5	2.5	4.0	3.0	4.5	3.0	6.0	3.0	6.5	3.0
196.2 to 392.5, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	4.0	3.0	5.5	3.0	6.0	3.0
392.5 to 588.8, excl	2.5	2.0	3.0	2.0	3.0	2.0	3.0	2.0	3.5	2.0	3.5	2.0	3.5	2.5	3.5	3.0	3.5	3.0	4.0	3.0	4.5	3.0
588.8 to 785.0, excl	2.5	1.5	2.5	1.5	2.5	1.5	2.5	1.5	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	2.5	2.0	3.0	2.0	3.5	2.0
785.0 to 1178, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0	3.5	1.0
1178 to 1962, excl	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	3.0	1.0
1962 to 2355, excl	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0
2355 to 2983, incl	2.0	1.0	2.0	1.0	2.0	1.0	2.0	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0	2.5	1.0

[A] The term "lot" means all the plates of each tabular width and mass group represented in each shipment.

TABLE A1.3
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR SHEARED PLATES 40 MM AND UNDER IN THICKNESS; LENGTH ONLY OF UNIVERSAL MILL PLATES 65 MM AND UNDER IN THICKNESS

Specified Dimensions, mm		Variations Over Specified Width and Length[A] for Thickness, mm, and Equivalent Masses, kg/m^2 Given							
		To 10.5 excl		10.5 to 16, excl		16 to 25, excl		25 to 50, incl[B]	
		To 78.50, excl		78.50 to 125.6, excl		125.6 to 196.2, excl		196.2 to 392.5, excl	
Length	Width	Width	Length	Width	Length	Width	Length	Width	Length
To 3000, excl	To 1500, excl	10	13	11	16	13	19	16	25
	1500 to 2100, excl	11	16	13	18	16	22	19	25
	2100 to 2700, excl	13	19	16	22	19	25	25	29
	2700 and over	16	22	19	25	22	29	29	32
3000 to 6000, excl	To 1500, excl	10	19	13	22	16	25	19	29
	1500 to 2100, excl	13	19	16	22	19	25	22	32
	2100 to 2700, excl	14	22	18	24	21	29	25	35
	2700 and over	16	25	19	29	22	32	29	35
6000 to 9000, excl	To 1500, excl	10	25	13	29	16	32	19	38
	1500 to 2100, excl	13	25	16	29	19	32	22	38
	2100 to 2700, excl	14	25	18	32	22	35	25	38
	2700 and over	18	29	22	32	25	35	32	44
9000 to 12 000, excl	To 1500, excl	11	29	13	32	16	35	19	41
	1500 to 2100, excl	13	32	16	35	19	38	22	41
	2100 to 2700, excl	14	32	19	35	22	38	25	48
	2700 and over	19	35	22	38	25	41	32	48
12 000 to 15 000, excl	To 1500, excl	11	32	13	38	16	41	19	48
	1500 to 2100, excl	13	35	16	38	19	41	22	48
	2100 to 2700, excl	16	35	19	38	22	41	25	48
	2700 and over	19	38	22	41	25	44	32	48
15 000 to 18 000, excl	To 1500, excl	13	44	16	48	19	48	22	57
	1500 to 2100, excl	16	44	19	48	22	48	25	57
	2100 to 2700, excl	16	44	19	48	22	48	29	57
	2700 and over	22	44	25	51	29	57	32	64
18 000 and over	To 1500, excl	14	51	19	54	22	57	25	70
	1500 to 2100, excl	19	51	22	54	25	57	29	70
	2100 to 2700, excl	19	51	22	54	25	57	32	70
	2700 and over	25	51	29	60	32	64	35	76

[A] Permissible variations under specified width and length, 6 mm.
[B] Permissible variations in length apply also to Universal Mill plates up to 300 mm in width for thicknesses over 50 to 65 mm, inc, except for alloy steel up to 50 mm thick.

TABLE A1.4
PERMISSIBLE VARIATIONS IN WIDTH FOR MILL EDGE CARBON AND HIGH STRENGTH LOW-ALLOY PLATES PRODUCED ON STRIP MILLS
(Applies to Either Plates Produced from Coils or Plates Produced in Discrete Cut Lengths of Flat Product)

Specified Width, mm	Variations Over Specified Width, mm[A]
To 360, excl	11
360 to 430, excl	13
430 to 480, excl	14
480 to 530, excl	16
530 to 610, excl	17
610 to 660, excl	21
660 to 710, excl	24
710 to 890, excl	29
890 to 1270, excl	32
1270 to 1520, excl	38
1520 to 1650, excl	41
1650 to 1780, excl	44
1780 to 2030, excl	47
2030 and over	51

[A] No permissible variation under specified width.

TABLE A1.5
PERMISSIBLE VARIATIONS IN ROLLED WIDTH FOR UNIVERSAL MILL PLATES 380 MM AND UNDER IN THICKNESS

	Variations Over Specified Width[A] for Thickness, mm, or Equivalent Masses, kg/m^2, Given					
	To 10, excl	10 to 16, excl	16 to 25, excl	25 to 50, incl	Over 50 to 250, incl	Over 250 to 400, incl
Specified Width, mm	To 78.50, excl	78.50 to 125.6, excl	125.6 to 196.2, excl	196.2 to 392.5, incl	Over 392.5 to 1962, incl	Over 1962 to 3140, incl
Over 200 to 500, excl	3	3	5	6	10	13
500 to 900, excl	5	6	8	10	11	14
900 and over	8	10	11	13	14	16

[A] Permissible variation under specified width, 3 mm.

TABLE A1.6
PERMISSIBLE VARIATIONS IN DIAMETER FOR SHEARED CIRCULAR PLATES 25 MM AND UNDER IN THICKNESS

Specified Diameters, mm	Permissible Variations Over Specified Diameter for Thicknesses Given, mm[A]		
To 800, excl	6	10	13
800 to 2100, excl	8	11	14
2100 to 2700, excl	10	13	16
2700 to 3300, excl	11	14	17
3300 and over	13	16	19

[A] No permissible variations under specified diameter.

TABLE A1.7
PERMISSIBLE VARIATIONS IN DIAMETER FOR GAS-CUT CIRCULAR PLATES
(Not Applicable to Alloy Steel)

Specified Diameters, mm	Variations Over Specified Diameter for Thicknesses Given, mm[A]					
	To 25, excl	25 to 50, excl	50 to 100, excl	100 to 150, excl	150 to 200, excl	200 to 400, incl
To 800, excl	10	10	13	13	16	19
800 to 2100, excl	10	13	13	16	19	22
2100 to 2700, excl	13	14	16	19	22	25
2700 to 3300, excl	13	14	17	22	25	29
3300 and over	16	19	22	25	29	32

[A] No permissible variations under specified diameter.

TABLE A1.8
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR RECTANGULAR PLATES WHEN GAS CUTTING IS SPECIFIED OR REQUIRED
(Applies to Alloy Steel Specifications Only)

Note 1 — Plates with universal rolled edges will be gas cut to length only.

Note 2 — These variations may be taken all under or divided over and under, if so specified.

Specified Thickness, mm	Variations Over for All Specified Widths or Lengths, mm
To 50, excl	19
50 to 100, excl	25
100 to 150, excl	29
150 to 200, excl	33
200 to 400, excl	38

TABLE A1.9
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR RECTANGULAR PLATES WHEN GAS CUTTING IS SPECIFIED OR REQUIRED
(Not Applicable to Alloy Steel)

Note — Plates with universal rolled edges will be gas cut to length only.

Specified Thickness, mm	Variations Over for All Specified Widths or Lengths, mm[A]
To 50, excl	13
50 to 100, excl	16
100 to 150, excl	19
150 to 200, excl	22
200 to 400, incl	25

[A] These variations may be taken all under or divided over and under, if so specified.

TABLE A1.10
PERMISSIBLE VARIATIONS IN DIAMETER FOR GAS-CUT CIRCULAR PLATES
(Applies to Alloy Steel Specifications Only)

Specified Diameter, mm	Variations Over Specified Diameter for Thickness Given, mm[A]					
	To 25, excl	25 to 50, excl	50 to 100, excl	100 to 150, excl	150 to 200, excl	200 to 400, incl
To 800, excl	13	13	19	19	25	25
800 to 2100, excl	13	16	22	25	29	32
2100 to 2700, excl	16	19	25	29	32	35
2700 to 3300, incl	22	25	29	32	35	38

[A] No permissible variations under specified diameter.

TABLE A1.11
PERMISSIBLE CAMBER[A] FOR CARBON STEEL, HIGH-STRENGTH LOW-ALLOY STEEL, AND ALLOY STEEL UNIVERSAL MILL PLATES AND HIGH-STRENGTH LOW-ALLOY STEEL AND ALLOY STEEL SHEARED OR GAS-CUT RECTANGULAR PLATES

Width, mm	Camber for Width Given, mm
To 750, incl	Length in millimetres/300
Over 750 to 1500	Length in millimetres/250

[A] Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE A1.12
PERMISSIBLE CAMBER[A] FOR SHEARED PLATES AND GAS-CUT RECTANGULAR PLATES ALL THICKNESSES
(Applies to Carbon Steel Only)

Maximum permissible camber, mm = length in millimetres/500

[A] Camber as it relates to plates is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

98

TABLE A1.13
PERMISSIBLE VARIATIONS FROM FLATNESS FOR CARBON STEEL PLATES

Note 1 — When the longer dimension is under 900 mm, the permissible variation should not exceed 6 mm. When the longer dimension is from 900 to 1800 mm, incl, the permissible variation should not exceed 75% of the tabular amount for the specified width, but in no case less than 6 mm.

Note 2 — These variations apply to plates that have a specified minimum tensile strength of not more than 400 MPa or comparable chemical composition or hardness. The limits in the table are increased 50% for plates specified to a higher minimum tensile strength or compatible chemistry or hardness.

Note 3 — This table and these notes cover the permissible variations for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

Note 4 — Where ". . ." appears in this table there is no requirement.

		Permissible Variations from a Flat Surface for Specified Widths, mm[A,B]										
Specified Thickness, mm	Specified Mass, kg/m^2	To 900, excl	900 to 1200, excl	1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, excl	3000 to 3600, excl	3600 to 4200, excl	4200 and over
To 6, excl	To 47.1, excl	14	19	24	32	35	38	41	44	48	. . .	. . .
6 to 10, excl	47.1 to 78.5, excl	13	16	19	24	29	32	35	38	41	. . .	. . .
10 to 12, excl	78.5 to 94.2, excl	13	14	16	16	19	22	25	29	32	48	54
12 to 20, excl	94.2 to 157.0, excl	11	13	14	16	16	19	25	25	29	38	51
20 to 25, excl	157.0 to 196.2, excl	11	13	14	16	16	16	19	22	25	35	44
25 to 50, excl	196.2 to 392.5, excl	10	13	13	14	14	16	16	16	18	29	38
50 to 100, excl	392.5 to 785.0, excl	8	10	11	13	13	13	13	14	16	22	29
100 to 150, excl	785.0 to 1178, excl	10	11	13	13	14	14	16	19	22	22	25
150 to 200, excl	1178 to 1570, excl	11	13	13	16	18	19	22	22	25	25	25
200 to 250, excl	1570 to 1962, excl	13	13	16	18	19	21	22	24	25	25	25
250 to 300, excl	1962 to 2355, excl	13	16	19	21	22	24	25	25	25	25	25
300 to 400, incl	2355 to 3140, incl	16	19	21	22	24	25	25	25	25	25	. . .

[A] *Flatness Variations for Length* — The longer dimension specified is considered the length, and permissible variations in flatness along the length should not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm of longer plates.

[B] *Flatness Variations for Width* — The flatness variations across the width should not exceed the tabular amount for the specified width.

TABLE A1.14
PERMISSIBLE VARIATIONS FROM FLATNESS FOR HIGH-STRENGTH LOW-ALLOY AND ALLOY STEEL PLATES, HOT ROLLED OR THERMALLY TREATED

98

Note 1 — When the longer dimension is under 900 mm the variation should not exceed 10 mm. When the larger dimension is from 900 to 1800 mm, incl, the variation should not exceed 75% of the tabular amount for the specified width.

Note 2 — This table and notes cover the tolerances for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

Note 3 — Where "..." appears in this table there is no requirement.

		Flatness Tolerances for Specified Widths, mm[A,B]										
Specified Thickness, mm	Specified Mass, kg/m^2	To 900, excl	900 to 1200, excl	1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, excl	3000 to 3600, excl	3600 to 4200, excl	4200 and over
To 6, excl	To 47.1, excl	21	29	35	48	51	57	60	67	70	...	...
6 to 10, excl	47.1 to 78.5, excl	19	24	29	35	44	48	51	57	60	...	...
10 to 12, excl	78.5 to 94.2, excl	19	22	24	24	29	33	38	41	48	70	79
12 to 20, excl	94.2 to 157.0, excl	16	19	22	22	25	29	32	35	41	57	76
20 to 25, excl	157.0 to 196.2, excl	16	19	22	22	24	25	29	33	38	51	67
25 to 50, excl	196.2 to 392.5, excl	14	16	19	21	22	24	25	25	25	41	57
50 to 100, excl	392.5 to 785.0, excl	13	14	18	19	19	19	19	22	25	32	41
100 to 150, excl	785.0 to 1178, excl	14	18	19	19	22	22	24	29	32	32	38
150 to 200, excl	1178 to 1570, excl	16	19	19	24	25	29	32	33	38	38	38
200 to 250, excl	1570 to 1962, excl	19	21	24	25	29	32	33	35	38	38	38
250 to 300, excl	1962 to 2355, excl	19	24	29	32	33	35	38	38	38	38	38
300 to 400, incl	2355 to 3140, incl	22	25	30	33	35	38	38	38	38	38	38

[A] *Flatness Variations for Length* — The longer dimension specified is considered the length, and variations from a flat surface along the length should not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm of longer plates.

[B] *Flatness Variations for Width* — The flatness variations across the width should not exceed the tabular amount for the specified width.

TABLE A1.15
PERMISSIBLE VARIATIONS IN WAVINESS FOR PLATES

Note 1 — Waviness denotes the maximum deviation of the surface of the plate from a plane parallel to the surface of the point of measurement and contiguous to the surface of the place at each of the two adjacent wave peaks, when the plate is resting on a flat horizontal surface, as measured in an increment of less than 4000 mm of length.

The waviness tolerance is a function of the flatness tolerance as obtained from Table A1.13 or A1.14 as appropriate.

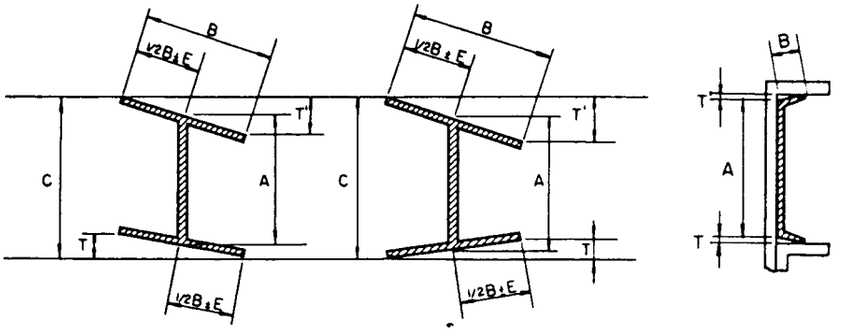
Flatness Tolerance, mm, from Tables A1.13 or A1.14	Waviness Tolerance, mm, When Number of Waves in 4000 mm is						
	1	2	3	4	5	6	7
8	8	6	5	3	3	2	2
10	10	8	5	5	3	2	2
11	11	8	6	5	3	3	2
13	13	10	8	5	5	3	2
14	14	11	8	6	5	3	2
16	16	13	10	6	5	3	2
17	17	13	10	8	5	5	2
19	19	14	11	8	6	5	2
21	21	16	11	8	6	5	2
22	22	17	13	10	6	5	2
24	24	17	13	10	8	6	5
25	25	19	14	11	8	6	5
29	29	22	16	13	10	6	5
32	32	24	17	13	10	8	6
35	35	27	19	14	11	8	6
38	38	29	22	16	13	10	6
41	41	32	24	17	13	10	8
44	44	33	25	19	14	11	8
48	48	37	27	21	14	11	8
51	51	38	29	22	16	13	10
54	54	41	30	22	17	13	10
57	57	43	32	24	17	14	10
60	60	46	33	25	19	14	11
64	64	48	37	27	21	14	11
67	67	51	38	29	21	16	11
70	70	52	40	29	22	16	13
73	73	56	41	30	24	17	13
76	76	57	43	32	24	17	14
79	79	60	44	33	25	19	14

TABLE A1.16
PERMISSIBLE VARIATIONS IN CROSS SECTION FOR W, HP, S, M, AND MC SHAPES

98

Note 1 — *A* is measured at center lines of web for S, M, W, and HP shapes; at back of web for C and MC shapes. Measurement is overall for C shapes under 75 mm. *B* is measured parallel to flange. *C* is measured parallel to web.

Note 2 — Where "..." appears in this table there is no requirement.



Shape	Section Nominal Size, mm	*A*, Depth, mm		*B*, Flange Width, mm		$T + T'$[A] Flanges Out-of-Square, max, mm[B]	*E*, Web off Center, max[C]	*C*, Maximum Depth at any Cross Section over Theoretical Depth, mm	Thickness of Web Over and Under for Thicknesses Given, mm	
		Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical				5 and Under	Over 5
W and HP	up to 310, incl	4	3	6	5	6	5	6	...	...
	over 310	4	3	6	5	8	5	6	...	...
S and M	75 to 180, incl	2	2	3	3	0.03	5	...	...	...
	over 180 to 360, incl	3	2	4	4	0.03	5	...	...	...
	over 360 to 610, incl	5	3	5	5	0.03	5	...	...	...
C and MC	40 and under	1	1	1	1	0.03	...	...	0.2	0.4
	over 40 to 75, excl	2	2	2	2	0.03	...	...	0.4	0.5
	75 to 180, incl	3	2	3	3	0.03	...	...	...	...
	over 180 to 360, incl	3	3	3	4	0.03	...	...	...	...
	over 360	5	4	3	5	0.03	...	...	...	...

[A] $T + T'$ applies when flanges of channels are toed in or out. For channels 16 mm and under in depth, the permissible out-of-square is 0.05 mm/mm of depth. The tolerance shall be rounded to the nearest millimetre after calculation.

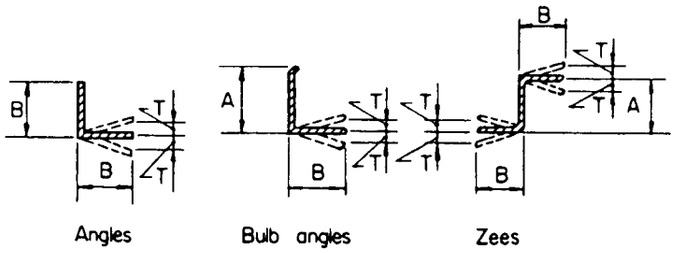
[B] Tolerance is per millimetre of flange width for S, M, C, and MC shapes.

[C] Variation of 8 mm max for sections over 634 kg/m.

98

TABLE A1.17
PERMISSIBLE VARIATIONS IN CROSS SECTION FOR ANGLES (L SHAPES), BULB ANGLES, AND ZEES

Note — Where "..." appears in this table there is no requirement.



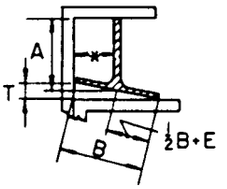
Section	Nominal Size, mm	*A*, Depth, mm		*B*, Flange Width, or Length of Leg, mm		*T*, Out-of-Square, per mm of *B*, mm	Variations from Thickness for Thicknesses Given, Over and Under, mm		
		Over Theoretical	Under Theoretical	Over Theoretical	Under Theoretical		5 and Under	Over 5 to 10	Over 10
Angles[A] (L shapes)	25 and under	...	...	1	1	0.026[B]	0.2	0.2	...
	over 25 to 50, incl	...	...	1	1	0.026[B]	0.2	0.2	0.3
	over 50 to 75, excl	...	...	2	2	0.026[B]	0.3	0.4	0.4
	75 to 100, incl	...	...	3	2	0.026[B]	...	...	...
	over 100 to 150 incl	...	...	3	3	0.026[B]	...	...	...
	over 150	...	...	5	3	0.026[B]	...	...	...
Bulb angles	(depth) 75 to 100, incl	3	2	4	2	0.026[B]	...	...	...
	over 100 to 150, incl	3	2	4	3	0.026[B]	...	...	...
	over 150	3	2	5	3	0.026[B]	...	...	...
Zees	75 to 100, incl	3	2	4	2	0.026[B]	...	...	...
	over 100 to 150, incl	3	2	4	3	0.026[B]	...	...	...

[A] For unequal leg angles, longer leg determines classification.
[B] 0.026 mm/mm = 1½°. The tolerance shall be rounded to the nearest millimetre after calculation.

TABLE A1.18
PERMISSIBLE VARIATIONS IN SECTIONAL DIMENSIONS FOR ROLLED TEES

98

Note 1 — * = Back of square and center line of stem are to be parallel when measuring "out-of-square."
Note 2 — Where ". . ." appears in this table there is no requirement.



Tees

Nominal Size,[A] mm	*A,* Depth,[B] mm		*B,* Width,[B] mm		*T,* Out-of-Square per mm of *B,* mm	*E,* Web-off-Center, max, mm	Stem Out-of-Square,[C] mm	Thickness of Flange, mm		Thickness of Stem, mm	
	Over	Under	Over	Under				Over	Under	Over	Under
30 and under	1	1	1	1	. . .	. . .	1	0.2	0.2	0.1	0.5
Over 30 to 50, incl	2	2	2	2	. . .	. . .	2	0.3	0.3	0.2	0.5
Over 50 to 75, excl	2	2	2	2	. . .	. . .	2	0.4	0.4	0.4	0.5
75 to 125, incl	2	2	3	3	0.03	2	. . .	. . .	. . .	. . .	. . .
Over 125 to 180, incl	2	2	3	3	0.03	3	. . .	. . .	. . .	. . .	. . .

[A] The longer member of an unequal tee determines the size for permissible variations.
[B] Measurements for both depth and width are overall.
[C] Stem-out-of-square is the variation from its true position of the center line of stem, measured at the point.

TABLE A1.19
PERMISSIBLE VARIATIONS IN LENGTH FOR S, M, C, MC, L, T, Z, AND BULB ANGLE SHAPES

98

Note — Where ". . ." appears in this table there is no requirement.

Nominal Size,[A] mm	Variations from Specified Length for Lengths Given, mm													
	1.5 to 3 m, excl		3 to 6 m, excl		6 to 9 m, incl		9 to 12 m, incl		12 to 15 m, incl		15 to 20 m, incl		Over 20 m	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 75	16	0	25	0	38	0	51	0	64	0	64	0	. . .	. . .
75 and over	13	6	13	6	13	6	19	6	25	6	29	6	32	6

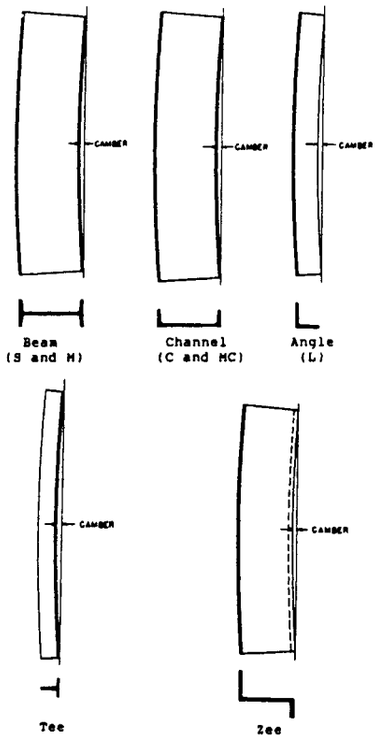
[A] Greatest cross-sectional dimension.

TABLE A1.20
PERMISSIBLE VARIATIONS IN ENDS OUT-OF-SQUARE FOR S, M, C, MC, L, T, Z, AND BULB ANGLE SHAPES

Shapes	Permissible Variations
S, M, C, and MC	0.017 mm/mm of depth
L[A]	0.026 mm/mm of leg length or 1½ deg
Bulb angles	0.026 mm/mm of depth or 1½ deg
Rolled tees[A]	0.017 mm/mm of flange or stem
Zees	0.026 mm/mm of sum of both flange lengths

[A] Permissible variations for ends out-of-square are determined on the longer members of the shape.
[B] The tolerance shall be rounded to the nearest millimetre after calculation.

TABLE A1.21
PERMISSIBLE VARIATIONS IN STRAIGHTNESS FOR S, M, C, MC, L, T, Z, AND BULB ANGLE SHAPES



Positions for Measuring Camber of Shapes

Variable	Nominal Size,[A] mm	Permissible Variation, mm
Camber	under 75	4 × number of metres of total length
	75 and over	2 × number of metres of total length
Sweep	all	Due to the extreme variations in flexibility of these shapes, straightness tolerances for sweep are subject to negotiations between the manufacturer and the purchaser for the individual sections involved.

[A] Greatest cross-sectional dimension.

TABLE A1.22
PERMISSIBLE VARIATIONS IN LENGTH FOR W AND HP SHAPES[A,B]

	Variations from Specified Length for Lengths Given, mm			
	9 m and Under		Over 9 m	
W Shapes	Over	Under	Over	Under
Beams 610 mm and under in nominal depth	10	10	10 plus 1 for each additional 1 m or fraction thereof	10
Beams over 610 mm in nominal depth and all columns	13	13	13 plus 1 for each additional 1 m or fraction thereof	13

[A] For HP shapes or W shapes when used as bearing piles, the length tolerance is plus 125 and minus 0 mm. This length tolerance also applies to steel sheet piles.

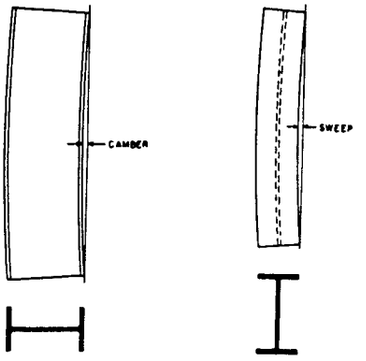
[B] The ends out-of-square tolerance for W and HP shapes shall be 0.016 mm/mm of depth, or of flange width if it is greater than the depth. The tolerance shall be rounded to the nearest millimetre after calculation.

TABLE A1.23
PERMISSIBLE VARIATIONS FOR LENGTH AND ENDS OUT-OF-SQUARE, MILLED SHAPES

		Milled Both Ends[B]			Milled One End[B]		
		Length, mm			Length, mm		
Nominal Depth, mm	Length,[A,C] *m*	Over	Under	Maximum End Out-of-Square, mm	Over	Under	Maximum End Out-of-Square-for Milled End, mm
150 to 920	2 to 21	1	1	1	6	6	1

[A] Length is measured along center line of web. Measurements are made with the steel and tape at the same temperature.
[B] Ends out-of-square are measured by *(a)* squaring from the center line of the web and *(b)* squaring from the center line of the flange. The measured variation from true squareness in either plane may not exceed the total tabular amount.
[C] Length variation and out-of-square variation are additive.

TABLE A1.24
PERMISSIBLE VARIATIONS IN STRAIGHTNESS FOR W AND HP SHAPES



Positions for Measuring Camber and Sweep of W and HP Shapes

	Permissible Variation
Camber and sweep	1 mm × number of metres of total length[A]
When certain section[B] with a flange width approximately equal to depth are specified on order as columns:	
Lengths of 14 mm and under	1 mm × number of metres of total length, but not over 10 mm
Lengths over 14 m	10 mm + [1 mm × (number of metres of total length − 14 mm)]

[A] Sections with a flange width less than 150 mm tolerance for sweep = 2 mm × number of metres of total length.
[B] Applies only to:
200-mm deep sections — 46.1 kg/m and heavier,
250-mm deep sections — 73 kg/m and heavier,
310-mm deep sections — 97 kg/m and heavier, and
360-mm deep sections — 116 kg/m and heavier.
If other sections are specified on the order as columns, the tolerance will be subject to negotiation with the manufacturer.

TABLE A1.25
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR SPLIT TEES AND SPLIT ANGLES (L SHAPES)[A]

Specified Depth, mm	Variations from Depth,[B] Over and Under, mm
To 150, excl (beams and channels)	3
150 to 410, excl (beams and channels)	5
410 to 510, excl (beams and channels)	6
510 to 610, excl (beams)	8
610 and over (beams)	10

[A] The length tolerance for split tees or angles are the same as those applicable to the section from which the tees or angles are split.

[B] The above tolerances for depth of tees or angles include the allowable tolerances in depth for the beams or channels before splitting. Tolerances both for dimensions and straightness, as set up for the beams or channels from which these tees or angles are cut, will apply, except

straightness = 2 mm × length in metres

98

TABLE A1.26
PERMISSIBLE VARIATIONS IN SECTIONAL DIMENSIONS FOR SQUARE-EDGE AND ROUND-EDGE FLAT BARS

Note — Where "..." appears in this table there is no requirement.

	Permissible Variations from Thickness, for Thicknesses Given, Over and Under, mm						Permissible Variations from Specified Width, mm	
Specified Widths, mm	Over 5 to 6, incl	Over 6 to 12, incl	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 75	Over 75	Over	Under
To 25, incl	0.18	0.20	0.25	...	...	...	0.5	0.5
Over 25 to 50, incl	0.18	0.30	0.40	0.8	...	...	1.0	1.0
Over 50 to 100, incl	0.20	0.40	0.50	0.8	1.2	1.2	1.5	1.0
Over 100 to 150, incl	0.25	0.40	0.50	0.8	1.2	1.2	2.5	1.5
Over 150 to 200, incl	[A]	0.40	0.65	0.8	1.2	1.6	3.0	2.5

[A] Flats over 150 to 200 mm, incl, in width are not available as hot-rolled bars in thickness 6 mm and under.

98

TABLE A1.27
PERMISSIBLE VARIATIONS IN SECTIONAL DIMENSIONS FOR ROUND AND SQUARE BARS AND ROUND-CORNERED SQUARES

Note — Where "..." appears in this table there is no requirement.

	Variations from Size, ±		Out-of-Round or Out-of-Square Section[A]	
Specified Sizes, mm	mm	%	mm	%
Up to 7.0, incl	0.13	...	0.20	...
Over 7.0 to 11.0, incl	0.15	...	0.22	...
Over 11.0 to 15.0, incl	0.18	...	0.27	...
Over 15.0 to 19.0, incl	0.20	...	0.30	...
Over 19.0 to 250, incl	...	1[B]	...	1½[B]

[A] Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same transverse cross section. Out-of-square section is the difference in perpendicular distance between opposite faces, measured at the same transverse cross section.

[B] The tolerance shall be rounded to the nearest tenth of a millimetre after calculation.

TABLE A1.28
PERMISSIBLE VARIATIONS IN SECTIONAL DIMENSIONS FOR HEXAGONS

Specified Sizes Between Opposite Sides, mm	Variation fron Specified Size, mm		Out-of-Hexagon Section, mm[A]
	Over	Under	
To 13 incl	0.18	0.18	0.3
Over 13 to 25 incl	0.25	0.25	0.4
Over 25 to 40 incl	0.55	0.35	0.6
Over 40 to 50 incl	0.8	0.40	0.8
Over 50 to 65 incl	1.2	0.40	1.2
Over 65 to 80 incl	1.6	1.6	

[A] Out-of-hexagon section is the greatest difference in distance between any two opposite faces measured at the same transverse cross section.

TABLE A1.29
PERMISSIBLE VARIATIONS IN STRAIGHTNESS FOR BARS

Maximum Permissible Variation in Straightness, mm[A]
6 mm in any 1500 mm, or (length in millimetres/250)[B]

[A] Permissible variations in straightness do not apply to hot-rolled bars if any subsequent heating operation has been performed.

[B] Round to the nearest whole millimetre.

98

TABLE A1.30
PERMISSIBLE VARIATIONS IN LENGTH FOR HOT-CUT STEEL BARS[A]

Note — Where "..." appears in this table there is no requirement.

Specified Sizes of Rounds, Squares, and Hexagons, mm	Specified Sizes of Flats, mm		Permissible Variations over Specified Length, mm (No Variation Under)				
	Thickness	Width	1500 to 3000, excl	3000 to 6000, excl	6000 to 9000, excl	9000 to 12 000, excl	12 000 to 18 000, excl
To 25, incl	to 25, incl	to 75, incl	15	20	35	45	60
Over 25 to 50, incl	over 25	to 75, incl	15	25	40	50	65
	to 25, incl	over 75 to 150, incl	15	25	40	50	65
Over 50 to 125, incl	over 25	over 75 to 150, incl	25	40	45	60	70
Over 125 to 250, incl	...	...	50	65	70	75	85
	over 6 to 25, incl	over 150 to 200, incl	20	30	45	90	100
	over 25 to 75, incl	over 150 to 200, incl	30	45	50	90	100
Bar size sections	...	...	15	25	40	50	65
		Hot Sawing					
50 to 125, incl	25 and over	75 and over	[B]	40	45	60	70
Over 125 to 250, incl	...	...	[B]	65	70	75	85

[A] For flats over 150 to 200 mm, incl, in width and over 75 mm in thickness, consult the producer for length tolerances.
[B] Smaller sizes and shorter lengths are not commonly hot sawed.

TABLE A1.31
PERMISSIBLE VARIATIONS IN LENGTH FOR BARS RECUT BOTH ENDS AFTER STRAIGHTENING[A,B]

Sizes of Rounds, Squares, Hexagons, Widths of Flats and Maximum Dimensions of Other Sections, mm	Permissible Variations for Specified Length, mm (No Variation Under)	
	to 3700, incl	over 3700
To 75, incl	6	8
Over 75 to 150, incl	8	11
Over 150 to 200, incl	11	14
Rounds over 200 to 250, incl	14	18

[A] For flats over 150 to 200 mm, incl, in width, and over 75 mm in thickness, consult the producer for length tolerances.
[B] Variations are sometimes required all over or all under the specified length, in which case the sum of the two tolerances applies.

APPENDICES

(Nonmandatory Information)

X1. COILED PRODUCT AS A SOURCE OF STRUCTURAL PLATES

X1.1 Continuous wide hot strip rolling mills are normally equipped with coilers. Regardless of the different types of systems employed during or following the rolling operations, it is common for the steel to be reeled into the coiler at temperatures in the stress-relieving range. In general, these temperatures are higher as material thickness increases. The coils subsequently cool to ambient temperature with outer and inner laps cooling more rapidly than central laps. The difference in cooling rate can result in measurable differences in the mechanical properties throughout a coil. Data confirm reduced yield and tensile strength with increased percent elongation for the product with slower cooling rates from the coiling temperature to ambient. These differences are in addition to the effects on mechanical properties caused by differences in heat analysis and chemical segregation.

X2. VARIATION OF TENSILE PROPERTIES IN PLATES AND STRUCTURAL SHAPES

X2.1 The tension testing requirements of Specification A 6/A 6M are intended only to characterize the tensile properties of a heat of steel for determination of conformance to the requirements of the material specifications. These testing procedures are not intended to define the upper or lower limits of tensile properties at all possible test locations within a heat of steel. It is well known and documented that tensile properties will vary within a heat or individual piece of steel as a function of chemical composition, processing, testing procedure, and other factors. It is, therefore, incumbent on designers and engineers to use sound engineering judgement when using tension test results shown on mill test reports. The testing procedures of Specification A 6/A 6M have been found to provide material adequate for normal structural design criteria.

X2.2 A survey of the variation to be expected in tensile properties obtained from plates and structural shapes was conducted by the American Iron and Steel Institute (AISI). The results of this survey are contained in a *Contributions to the Metallurgy of Steel* entitled "The Variation of Product Analysis and Tensile Properties — Carbon Steel Plates and Wide Flange Shapes" (SU/18, SU/19, and SU/20), published in September 1974. The data are presented in tables of probability that tensile properties at other than the official location may differ from those of the reported test location.

X2.3 Specification A 6/A 6M contains no requirements applicable to product tension tests; conformance to the material specifications is determined on the basis of tests performed at the place of manufacture prior to shipment, unless otherwise specified.

X2.4 A Task Group of ASTM Subcommittee A01.02 has determined, based on review of the AISI data, that the variation in tensile properties of plates and structural shapes can be expressed as a function of specified requirements: one standard deviation equals approximately 4% of required tensile strength, 8% of required yield strength, and 3 percentage units of required elongation.

X2.5 Acceptance criteria for product testing based on these values either below the minimum or above the maximum allowed by the material specification are generally acceptable to material manufacturers. Such tolerances could be considered by users of this product as a reasonable basis for acceptance of materials which, due to their inherent variability, deviate from material specification requirements when subjected to product tension testing.

X3. WELDABILITY OF STEEL

X3.1 *Weldability* is a term that usually refers to the relative ease with which a metal can be welded using conventional practice. Difficulties arise in steel when the cooling rates associated with weld thermal cycles produce microstructures (for example, martensite) that are susceptible to brittle fracture or, more commonly, hydrogen-induced (or *cold*) cracking. (Solidification or *hot* cracking is a relatively rare phenomenon that will not be addressed here. See Randall for further information.)

X3.2 The relative sensitivity of steels to forming cold cracking microstructures is called hardenability and can be measured in a number of ways. Perhaps

the most popular method of assessing this is by the carbon equivalent (CE) formula, which attempts to equate the relative hardening contributions of a steel's constituent elements (for example, manganese, vanadium) to an equivalent amount of carbon, which is the most significant hardening agent. The most popular formula is the IIW (International Institute of Welding) equation presented in S74.2, which has been found suitable for predicting hardenability in a wide range of commonly used carbon-manganese and low alloy steels.

X3.3 It should be noted, however, that for the current generation of low carbon (<0.10%) low alloy steels that derive strength from a combination of microalloys and thermal processing methods, the use of other formulae may more accurately assess hardenability and cold cracking sensitivity.

X3.4 For a vast number of common structural applications it is unnecessary to specify the use of CE limits. However, in order to obtain a higher level of confidence in avoiding cold cracking, the chemistry controls in S74 are available. A purchaser who specifies the use of S74 should be aware that there are several factors involved in the judicious selection of a maximum CE value, such as the following:

X3.4.1 Actual production joint restraint/base metal thickness(es),

X3.4.2 Filler metal and base metal strength compatibility,

X3.4.3 Deposited weld metal diffusible hydrogen content,

X3.4.4 Preheat and interpass temperatures,

X3.4.5 Filler metal and base metal cleanliness, and

X3.4.6 Heat input.

X3.5 Though it is widely believed that *low* CE steels are immune to weld cracking problems, failure to consider these factors and others have resulted in weld or base metal HAZ (heat affected zone) cracks in such steels.

X3.6 It is important to note that carbon equivalence is only a qualitative assessment of potential welding problems, and should never be solely relied on to ensure weld integrity. The proper use of welding specifications, coupled with the knowledge of actual construction conditions, must also be used.

SPECIFICATION FOR GENERAL REQUIREMENTS FOR STEEL PLATES FOR PRESSURE VESSELS

SA-20/SA-20M

(Identical with ASTM Specification A 20/A 20M-96a$^{\epsilon 1}$) 98

1. Scope

98 **1.1** This specification covers a group of common requirements which, unless otherwise specified in the individual material specification, shall apply to rolled steel plates for pressure vessels under each of the following specifications issued by ASTM:

Title of Specification	ASTM Designation
Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon	A 202/A 202M
Pressure Vessel Plates, Alloy Steel, Nickel	A 203/A 203M
Pressure Vessel Plates, Alloy Steel, Molybdenum	A 204/A 204M
Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium	A 225/A 225M
Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength	A 285/A 285M
Pressure Vessel Plates, Carbon Steel, Manganese-Silicon	A 299/A 299M
Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel	A 302/A 302M
Pressure Vessel Plates, Alloy Steel, 9 Percent Nickel, Double-Normalized and Tempered	A 353/A 353M
Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum	A 387/A 387M
Pressure Vessel Plates, Carbon Steel, Improved Transition Properties	A 442/A 442M
Pressure Vessel Plates, Carbon Steel, High Strength Manganese	A 455/A 455M
Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service	A 515/A 515M
Pressure Vessel Plates, Carbon Steel, Moderate- and Lower-Temperature Service	A 516/A 516M
Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered	A 517/A 517M
Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Manganese-Molybdenum and Manganese-Molybdenum-Nickel	A 533/A 533M
Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel	A 537/A 537M
Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Chromium-Molybdenum	A 542/A 542M
Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum	A 543/A 543M
Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9 Percent Nickel	A 553/A 553M
Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings	A 562/A 562M
Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate and Lower Temperature Service	A 612/A 612M
Pressure Vessel Plates, Five Percent Nickel Alloy Steel, Specially Heat Treated	A 645/A 645M
Pressure Vessel Plates, Carbon-Manganese, for Moderate and Lower Temperature Service	A 662/A 662M
Pressure Vessel Plates, Carbon Steel, Quenched and Tempered, for Welded Layered Pressure Vessels	A 724/A 724M
Pressure Vessel Plates, Alloy Steel and High-Strength Low-Alloy Steel, Quenched and Tempered	A 734/A 734M
Pressure Vessel Plates, Low-Carbon Manganese-Molybdenum-Columbium Alloy Steel, for Moderate and Lower Temperature Service	A 735/A 735M
Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium Alloy Steel	A 736/A 736M

Title of Specification	ASTM Designation
Pressure Vessel Plates, High-Strength, Low-Alloy Steel	A 737/A 737M
Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service	A 738/A 738M
Pressure Vessel Plates, Quenched and Tempered Manganese-Chromium-Molybdenum-Silicon-Zirconium Alloy Steel	A 782/A 782M
Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Vanadium	A 832/A 832M
Pressure Vessel Plates, Produced by the Thermo-Mechanical Control Process (TMCP)	A 841/A 841M
Pressure Vessel Plates, 9% Nickel Alloy, Produced by the Direct-Quenching Process	A 844/A 844M

1.1.1 This specification also covers a group of supplementary requirements which are applicable to several of the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.2 Appendix X1 describes the production and some of the characteristics of coiled product from which pressure vessel plates may be produced.

98 **1.3** Appendix X2 provides information on the variability of tensile properties in plates for pressure vessels.

98 **1.4** Appendix X3 provides information on the variability of Charpy-V-Notch impact test properties in plates for pressure vessels.

98 **1.5** These materials are intended to be suitable for fusion welding. When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized.

98 **1.6** In case of any conflict in requirements, the requirements of the individual material specification shall prevail over those of this general specification.

98 **1.7** The purchaser may specify additional requirements which do not negate any of the provisions of this general specification or of the individual material specifications. Such additional requirements, the acceptance of which are subject to negotiation with the supplier, must be included in the order information (see 4.1.8).

98 **1.8** For purposes of determining conformance with this specification and the various material specifications referenced in 1.1, values shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values in accordance with the rounding method of Practice E 29.

1.9 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification. 98

1.10 This specification and the applicable material specifications are expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units. 98

2. Referenced Documents

2.1 *ASTM Standards:* 98

A 202/A 202M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon

A 203/A 203M Specification for Pressure Vessel Plates, Alloy Steel, Nickel

A 204/A 204M Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum

A 225/A 225M Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Vanadium-Nickel

A 285/A 285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength

A 299/A 299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon

A 302/A 302M Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel

A 353/A 353M Specification for Pressure Vessel Plates, Alloy Steel, 9 Percent Nickel, Double-Normalized and Tempered

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 387/A 387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 442/A 442M Specification for Pressure Vessel Plates, Carbon Steel, Improved Transition Properties

A 455/A 455M Specification for Pressure Vessel Plates, Carbon Steel, High Strength Manganese

A 515/A 515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service

A 516/A 516M Specification for Pressure Vessel Plates, Carbon Steel, Moderate- and Lower-Temperature Service
A 517/A 517M Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered
A 533/A 533M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Manganese-Molybdenum and Manganese-Molybdenum-Nickel
A 537/A 537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel
A 542/A 542M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Chromium-Molybdenum, and Chromium-Molybdenum-Vanadium
A 543/A 543M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum
A 553/A 553M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9 Percent Nickel
A 562/A 562M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings
A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates
A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications
A 612/A 612M Specification for Pressure Vessel Plates, Carbon Steel, High Strength, for Moderate and Lower Temperature Service
A 645/A 645M Specification for Pressure Vessel Plates, Five Percent Nickel Alloy Steel, Specially Heat Treated
A 662/A 662M Specification for Pressure Vessel Plates, Carbon-Manganese, for Moderate and Lower Temperature Service
A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
A 724/A 724M Specification for Pressure Vessel Plates, Carbon Steel, Quenched and Tempered, for Welded Layered Pressure Vessels
A 734/A 734M Specification for Pressure Vessel Plates, Alloy Steel and High-Strength Low-Alloy Steel, Quenched and Tempered
A 735/A 735M Specification for Pressure Vessel Plates, Low-Carbon Manganese-Molybdenum-Columbium Alloy Steel, for Moderate and Lower Temperature Service
A 736/A 736M Specification for Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium and Nickel-Copper-Manganese-Molybdenum-Columbium Alloy Steel
A 737/A 737M Specification for Pressure Vessel Plates, High-Strength, Low-Alloy Steel
A 738/A 738M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 770/A 770M Specification for Through-Thickness Tension Testing of Steel Plates for Special Applications
A 782/A 782M Specification for Pressure Vessel Plates, Quenched and Tempered Manganese-Chromium-Molybdenum-Silicon-Zirconium Alloy Steel
A 832/A 832M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum-Vanadium
A 841/A 841M Specification for Steel Plates for Pressure Vessels, Produced by the Thermo-Mechanical Control Process (TMCP)
A 844/A 844M Specification for Steel Plates, 9% Nickel Alloy, for Pressure Vessels, Produced by the Direct-Quenching Process
E 21 Practice for Elevated Temperature Tension Tests of Metallic Materials
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 44 Definitions of Terms Relating to Heat Treatment of Metals
E 112 Test Methods for Determining Average Grain Size
E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels
E 709 Practice for Magnetic Particle Examination

2.2 *American Society of Mechanical Engineers Code:*
ASME Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

2.3 *U.S. Military Standard:*
MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage

2.4 *U.S. Federal Standard:*
Fed. Std. No. 123, Marking for Shipment (Civil Agencies)

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *capped steel* — rimmed steel in which the rimming action is limited by an early capping operation. Capping may be carried out mechanically by using a heavy metal cap on a bottle-top mold or

it may be carried out chemically by an addition of aluminum or ferrosilicon to the top of the molten steel in an open-top mold.

3.1.2 *exclusive* — when used in relation to ranges, as for ranges of thicknesses in the tables of permissible variations in dimensions, the term is intended to exclude only the greater value of the range. Thus, a range from 60 to 72 in. [1500 to 1800 mm] *exclusive* includes 60 in. [1500 mm], but does not include 72 in. [1800 mm].

3.1.3 *heat treatment terms* — see 3.7, 3.10, and Definitions E 44.

3.1.4 *hot forming* — a forming operation producing permanent deformation, performed after the plate has been heated to the temperature required to produce grain refinement.

3.1.5 *killed steel* — steel deoxidized, either by addition of strong deoxidizing agents or by vacuum treatment, to reduce the oxygen content to such a level that no reaction occurs between carbon and oxygen during solidification.

3.1.6 *manufacturer (material manufacturer)* — an organization that performs or directly controls one or more operations, such as melting, rolling, coiling, and heat treating, that affect the chemical composition or mechanical properties of the material.

3.1.7 *normalizing* — a heat treating process in which a steel plate is reheated to a uniform temperature above the upper critical temperature and then cooled in air to below the transformation range.

3.1.8 *plate-as-rolled* — when used in relation to the location and number of tests, the term refers to the unit plate rolled from a slab or directly from an ingot. It does not refer to the condition of the plate.

3.1.9 *plates* — flat hot-rolled steel, commonly available by size as follows:

Width, in. [mm]	Thickness, in. [mm]
Over 8 [200]	Over 0.229 [6.0 mm and over]
Over 48 [1200]	Over 0.179 [4.6 mm and over]

3.1.10 *precipitation heat treatment* — a subcritical temperature thermal treatment performed to cause precipitation of submicroscopic constituents, etc., to result in enhancement of some desirable property.

3.1.11 *processor* — an organization that performs operations, such as decoiling, cutting to length, marking, inspecting, examining, and testing.

3.1.12 *rimmed steel* — steel containing sufficient oxygen to give a continuous evolution of carbon monoxide while the ingot is solidifying, resulting in a case or rim of metal virtually free of voids.

3.1.13 *semikilled steel* — incompletely deoxidized steel containing sufficient oxygen to form enough carbon monoxide during solidification to offset solidification shrinkage.

4. Ordering Information

4.1 Orders should include the following information, as necessary, to adequately describe the desired material.

4.1.1 Quantity (weight or number of plates),

4.1.2 Dimensions,

4.1.3 Name of material (plates, carbon steel; plates, alloy steel),

4.1.4 Specification designation (including type, class, and grade as applicable) and year of issue,

4.1.5 Condition (as-rolled, normalized, quenched and tempered, etc. If heat treatment of material is to be performed by the fabricator, this must be so stated. Also, if purchaser specifies a heat-treatment cycle, it must be stated.)

4.1.6 Impact test requirements, if any (Section 12.) (For Charpy V-notch test, include specimen orientation, testing temperature, and acceptance criteria. For drop-weight test give testing temperature.),

4.1.7 Either plates from coil or discrete cut lengths of flat product may be supplied unless one is specifically excluded on the order (see Appendix X1),

4.1.8 If the processor (see 5.5.2) intends to qualify plates cut from a coiled product as pressure vessel plates, the order to the manufacturer (see 5.5.1) should state the intended ASTM specification designation, grade, and type (as applicable),

4.1.9 Supplementary requirements, if any (test specimen heat treatment, special impact test requirements, etc.), and

4.1.10 Additional requirements, if any.

5. Manufacture

5.1 The steel shall be produced by one of the following primary steelmaking processes: open hearth, basic oxygen, electric furnace. The steel may be further

refined by secondary processes, including but not restricted to: vacuum-secondary processes, including but not restricted to: vacuum-arc remelt (VAR) electroslag remelt (ESR), and ladle treatment.

5.2 The steel may be cast in ingots or may be strand cast.

5.2.1 *Strand Cast Slabs:*

5.2.1.1 When heats of the same nominal chemical composition are consecutively strand cast at one time, the heat number assigned to the cast product (slab) may remain unchanged until all of the steel in the slab is from the following heat.

5.2.1.2 When two consecutively strand cast heats have different nominal chemical composition ranges, the manufacturer shall remove the transition material by any established procedure that positively separates the grades.

5.3 The ratio of reduction of thickness from a strand-cast slab to plate shall be a minimum of 3 to 1.

5.4 Plates are produced in either discrete cut lengths of flat product or from coils.

5.4.1 Plates produced from coil means plates that have been leveled or flattened and cut to length from a coiled product and that are furnished without heat treatment. For the purposes of this paragraph, stress relieving is not considered to be a heat treatment.

5.4.2 Plates that are annealed, normalized, normalized-and-tempered, or quenched-and-tempered after decoiling shall be considered to be discrete cut lengths of flat products.

5.5 When plates are produced from coils:

5.5.1 The manufacturer directly controls one or more of the operations (that is, melting, rolling, coiling, etc.) that affect the chemical composition or the mechanical properties, or both, of the material.

5.5.2 The processor decoils, cuts to length, and marks; performs and certifies tests, examination repairs, inspection, or operations not intended to affect the properties of the material. The processor may subsequently heat treat the plates (see Section 6). Specific sections of this specification for which the processor is responsible are 9, 10, 11, 12, 13, 14, 15, 16, 19, and 20.

5.5.3 Plates produced from coils shall not contain splice welds, unless approved by the purchaser.

6. Heat Treatment

6.1 When material is required to be heat treated, the heat treatment may be performed either by the manufacturer or processor or by the fabricator unless otherwise specified in the material specification.

6.2 When the heat treatment required by the material specification is to be performed by the purchaser or the purchaser's agent, and the material is to be supplied by the material producer in a condition other than that required by the material specification, the order shall so state.

6.2.1 When plates are ordered without the heat treatment required by the material specification, heat treatment of the plates to conform to the requirements of the material specification shall be the responsibility of the purchaser.

6.3 When heat treatment is to be performed, the material shall be heat treated as specified in the material specification. The purchaser may specify the heat treatment to be used provided it is not in conflict with the requirements of the material specification.

6.4 When normalizing is to be performed by the fabricator, it may be accomplished by heating uniformly for hot forming. The temperature to which the plates are heated for hot forming shall not significantly exceed the normalizing temperature.

6.5 When no heat treatment is required, the manufacturer or processor may opt to heat treat the plates by normalizing, stress relieving, or normalizing and then stress relieving to meet the material specification.

6.6 If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible to achieve specified mechanical properties, provided the plates are subsequently tempered in the temperature range from 1100 to 1300°F [595 to 705°C].

7. Chemical Analyses

7.1 *Heat Analysis* of each heat shall be made by the manufacturer to determine the percentage of elements specified in the individual material specification. This analysis shall be made from a test specimen preferably taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser, or the purchaser's representative, and shall conform to the heat analysis requirements of the applicable specification.

7.1.1 Unspecified elements may be present. Unless otherwise specified in the material specification, limits on elements shall be as stated in Table 1.

7.1.1.1 Each of the elements listed in Table 1 shall be included in the report of the heat analysis. When the amount of an element present is less than 0.02%, the analysis may be reported as "<0.02%".

7.2 *Product Analysis* representing each plate as-rolled may be made by the purchaser from a broken tension test specimen or from a sample taken from the same relative location as that from which the tension test specimen was obtained. The chemical composition thus determined, as to elements required or restricted, shall conform to the product analysis requirements specified in the applicable specification.

7.3 *Referee Analysis* — For referee purposes, Test Methods, Practices, and Terminology A 751 shall be used.

8. Metallurgical Structure

8.1 When a coarse austenitic grain size is specified, the steel shall have a carburized austenitic grain size number of 1 to 5 as determined by the McQuaid-Ehn test. Determination shall be in accordance with Methods E 112, Plate IV, by carburizing for 8 h at 1700°F [925°C]. Conformance to this grain size of 70% of the grains in the area examined shall constitute the basis of acceptance. One test per heat shall be made.

8.2 *Fine Austenitic Grain Size:*

8.2.1 When a fine austenitic grain size is specified, aluminum shall be used as the grain refining element unless the order provides otherwise as specified in 8.2.4.

8.2.2 When a fine austenitic grain size is specified, except as otherwise provided in 8.2.2.1, the steel shall have a carburized austenitic grain size number of 5 or higher (finer) as determined by the McQuaid-Ehn test in accordance with Methods E 112, Plate IV. One test per heat shall be made.

8.2.2.1 When aluminum is used as the grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the aluminum content is not less than 0.020% total aluminum or, alternately, 0.015% acid soluble aluminum.

8.2.3 When specified on the order, one McQuaid-Ehn test (see 8.1) per heat shall be made and the austenitic grain size of the steel, as represented by the test, shall be Number 5 or finer.

8.2.4 By agreement between the purchaser and the supplier, elements other than aluminum may be used for grain refining. In such instances, the heat analysis limits for the element, or elements, permitted shall be specified on the order. In addition, the McQuaid-Ehn test of 8.2.3 shall be required.

9. Quality

9.1 *General* — Plates furnished under this specification shall be free of injurious defects and shall have a workmanlike finish.

9.2 *Surface Imperfections:*

9.2.1 All injurious surface imperfections shall be removed by the manufacturer of discrete cut length plates. For plates provided from coils, the processor shall remove the injurious imperfections, rather than the manufacturer.

9.2.1.1 Shallow imperfections shall be ground to sound metal; the ground area shall be well faired and the thickness of the ground plate shall not be reduced below the minimum thickness permitted.

9.2.1.2 All surface imperfections, the removal of which will reduce the plate thickness below this minimum, shall be cause for rejection of the plate; however, by agreement with the purchaser, the metal so removed may be replaced with weld metal as provided in 9.4.

9.3 *Edge Imperfections:*

9.3.1 Laminar-type discontinuities 1 in. [25 mm] and less in length visible to the unaided eye on the edges of a plate as prepared for shipment by the manufacturer or processor are acceptable and do not require exploration.

9.3.2 All larger discontinuities shall be explored to determine their depth and extent. Discontinuities shall be considered continuous when located in the same plane within 5% of the plate thickness and separated by a distance less than the length of the smaller of two adjacent discontinuities.

9.3.3 Indications visible to the unaided eye on the cut edges of a plate as prepared for shipment by the manufacturer or processor shall not exceed the limits given in columns 1 and 2 of Table A1.14 [A2.14].

9.3.4 Larger indications shall be removed by the manufacturer or processor by grinding provided the resultant cavity does not exceed the limits given in columns 3 and 4 of Table A1.14 [A2.14].

9.3.5 Indications of greater magnitude shall be cause for rejection of a plate; however, by agreement with the purchaser, the defects may be removed and replaced with weld metal as provided in 9.4.

9.3.6 Indications on the edges of a plate cut during the fabrication shall be cause for rejection of the plate at the discretion of the purchaser when the magnitude exceeds the limits given in columns 5 and 6 of Table A1.14 [A2.14]. The defects may be removed and replaced with weld metal as provided in 9.4.

9.3.7 Fabricators should be aware that edge cracks may initiate upon bending a sheared or burned edge during the fabrication process. This is not considered to be a fault of the steel, but is rather a function of the induced cold work or heat affected zone.

9.4 *Repair by Welding:*

9.4.1 Repair welding shall be permitted only with the approval of the purchaser.

9.4.2 Preparation for repair welding shall include inspection to assure complete removal of the defect.

9.4.3 Repairs shall be made utilizing welding procedures qualified in accordance with Section IX of the ASME Code and repair welding shall be done by welders or welding operators meeting the qualification requirements of ASME Section IX.

9.4.4 The weld metal shall have the A-number analysis corresponding to the equivalent ASME P number of the plate material except that A-1 or A-2 analysis weld metal may be employed for P-1 materials. Other weld metals may be employed that are compatible with the base material being repaired, when so approved by the purchaser. Such weld metals must be qualified in accordance with the requirements of Section IX of the ASME Code.

9.4.5 If Charpy impact tests are required on the plate material, the welding procedure qualification tests shall also include Charpy impact tests of the weld, heat affected zone, and plate material and shall be reported to the purchaser.

9.4.6 If the plate material is subjected to normalizing, quenching and tempering, hot forming, or postweld heat treating, the welding procedure qualification test plates and the weld repaired plate shall be subjected to the thermal heat treatment as specified by the purchaser.

9.4.7 In addition, repair welds shall meet the requirements of the construction code specified by the purchaser.

10. Test Methods

10.1 All tests shall be conducted in accordance with Test Methods and Definitions A 370.

10.2 Yield strength may be determined either by the 0.2% offset method or the 0.5% extension under load method unless otherwise stated in the material specification.

10.3 *Rounding Procedures* — For purposes of determining conformance with the specification, a calculated value shall be rounded to the nearest 1 ksi [5 MPa] tensile and yield strength, and to the nearest unit in the right-hand place of figures used in expressing the limiting value for other values in accordance with the rounding method given in Practice E 29.

11. Tension Tests

11.1 *Number of Tests* — Except as specified in 11.1.1, one tension test shall be taken from each plate-as-rolled, except for plates subjected to heat treatment by quenching and tempering. Two tension tests shall be taken from each quenched and tempered plate. When plates are furnished by the manufacturer or processor in accordance with 11.4.2 and qualified by heat-treated specimens (including normalized, normalized and tempered, and quenched and tempered), one tension test specimen shall be taken from each plate-as-rolled (see 3.8 for the definition of plate-as-rolled).

11.1.1 *Plates Produced from Coils* — When plates are produced from coils, a minimum of three tension tests shall be made from each coil qualified, except as otherwise indicated below for qualification of a portion of a coil.

11.1.1.1 The first test coupon shall be taken immediately prior to the first plate produced to the qualifying specification, the second test coupon shall be taken from the approximate center lap, and the third test coupon shall be taken immediately after the last plate produced to the qualifying specification. If, during decoiling, the amount of material decoiled is less than that required to reach the next standard test location, a test for qualification of that particular shipment may

be made from a test coupon taken from a location adjacent to the innermost portion shipped.

11.1.1.2 All material between any two test locations that meet the requirements of the material specification is acceptable.

11.1.1.3 All material between a test location that fails to meet the requirements of the material specification and an adjacent acceptable test is rejectable. However, other tests may be made after cutting back the coil in either direction.

11.2 *Orientation of Tests* — The longitudinal axis of the tension-test specimens shall be transverse to the final rolling direction of the plate.

11.3 *Location of Tests* — The tension test specimen shall be taken from a corner of the plate. For quenched and tempered plates, the tension test specimens shall be taken from a corner of the plate at both ends of the plate.

11.4 *Tests from Heat-Treated Plates:*

11.4.1 When heat treatment is performed by the manufacturer or processor, the test specimens shall be taken from the plate in the heat-treated condition or from full-thickness coupons simultaneously heat treated with the plate.

11.4.2 When heat treatment is to be performed by the fabricator, the plates shall be accepted on the basis of tests made on specimens taken from full thickness coupons heat treated in accordance with the requirements specified in the material specification or on the order. If the heat-treatment temperatures are not specified, the manufacturer or processor shall heat treat the coupons under conditions he considers appropriate. The purchaser shall be informed of the procedure followed in heat treating the specimens.

11.4.3 When approved by the purchaser, the procedures of paragraph 11.4.2 may be implemented on plates heat treated by the manufacturer or processor.

11.4.4 When the plate is heat treated with a cooling rate faster than still-air cooling from the austenitizing temperature, one of the following shall apply in addition to other requirements specified herein:

11.4.4.1 The gage length of the tension test specimen shall be taken at least 1*T* from any as-heat treated edge where *T* is the thickness of the plate and shall be at least ½ in. [12.5 mm] from flame cut or heat-affected-zone surfaces.

11.4.4.2 A steel thermal buffer pad, 1*T* by 1*T* by at least 3*T*, shall be joined to the plate edge by a partial penetration weld completely sealing the buffered edge prior to heat treatment.

11.4.4.3 Thermal insulation or other thermal barriers shall be used during the heat treatment adjacent to the plate edge where specimens are to be removed. It shall be demonstrated that the cooling rate of the tension test specimen is no faster than, and not substantially slower than, that attained by the method described in 11.4.4.2.

11.4.4.4 When test coupons cut from the plate but heat treated separately are used, the coupon dimensions shall be not less than 3*T* by 3*T* by *T* and each tension specimen cut from it shall meet the requirements of 11.4.4.1.

11.4.4.5 If cooling rate data for the plate and cooling rate control devices for the test specimens are available, the test specimens may be heat treated separately in the device. This method shall require prior approval of the purchaser.

11.5 *Specimen Preparation:*

11.5.1 Tension test specimens for plates ¾ in. [20 mm] and under in thickness shall be the full thickness of the plates. The test specimens shall conform to the requirements for either the 1½ in. [40 mm] wide or the ½ in. [12.5 mm] wide rectangular tension test specimen of Methods and Definitions A 370. The 1½ in. [40 mm] wide specimen may have both edges parallel. The ½ in. [12.5 mm] wide specimen may have a maximum nominal thickness of ¾ in. [20 mm].

11.5.2 For plates up to 4 in. [100 mm], inclusive, in thickness, tension test specimens may be the full thickness of the material and conform to the requirements for the 1½ in. [40 mm] wide rectangular tension test specimen of Methods and Definitions A 370 when adequate testing machine capacity is available.

11.5.3 For plates over ¾ in. [20 mm] in thickness, except as permitted in 11.5.2, tension test specimens shall conform to the requirements for the 0.500 in. [12.5 mm] round specimen of Methods and Definitions A 370. The axis of the specimen shall be located, as nearly as practicable, midway between the center of thickness and the top or bottom surface of the plate.

11.6 *Elongation Requirement Adjustments:*

11.6.1 Due to the specimen geometry effect encountered when using the rectangular tension test specimen for testing thin material, adjustments in elongation **98**

requirements must be provided for thicknesses under 0.312 in. [8 mm]. Accordingly, the following deductions shall be made from the base elongation requirements in the individual plate specifications:

Nominal Thickness Range, in. [mm]	Elongation Deduction, %
0.299–0.311 [7.60–7.99]	0.5
0.286–0.298 [7.30–7.59]	1.0
0.273–0.285 [7.00–7.29]	1.5
0.259–0.272 [6.60–6.99]	2.0
0.246–0.258 [6.20–6.59]	2.5
0.233–0.245 [5.90–6.19]	3.0
0.219–0.232 [5.50–5.89]	3.5
0.206–0.218 [5.20–5.49]	4.0
0.193–0.205 [4.90–5.19]	4.5
0.180–0.192 [4.60–4.89]	5.0

98 **11.6.2** Due to the inherently lower elongation which is obtainable in thicker material, adjustments in elongation requirements in 2 in. [50 mm] gage length must be provided for thicknesses over 3.5 in. [90 mm]. Accordingly, the following deductions shall be made from the base elongation requirements in 2 in. [50 mm] listed in the individual plate specifications:

Plate Nominal Thickness Range, in. [mm]	Elongation Deduction, %
3.501–3.999 [90.00–102.49]	0.5
4.000–4.499 [102.50–114.99]	1.0
4.500–4.999 [115.00–127.49]	1.5
5.000–5.499 [127.50–139.99]	2.0
5.500–5.999 [140.00–152.49]	2.5
6.000 and thicker [152.50 and thicker]	3.0

11.6.3 A characteristic of certain types of alloy steels is a local disproportionate increase in the degree of necking down or contraction of the specimens under tension test, resulting in a decrease in the percentage of elongation as the gage length is increased. The effect is not so pronounced in the thicker plates. On such material, when so stated in the material specification for plates up to $\frac{3}{4}$ in. [20 mm], inclusive, in thickness, if the percentage of elongation of an 8 in. [200 mm] gage length test specimen falls not more than 3% below the amount prescribed, the elongation shall be considered satisfactory provided the percentage of elongation in 2 in. [50 mm] across the break is not less than 25%.

11.6.4 The tensile requirements tables in many of the plate specifications covered by these general requirements specify elongation requirements in both 8 in. [200 mm] and 2 in. [50 mm] gage lengths. Unless otherwise provided in the individual plate specification, it is not the intent that both requirements apply simultaneously and that the elongation be determined in both gage lengths. Instead, it is intended that the elongation be determined only in the gage length appropriate for the test specimen used. After selection of the appropriate gage length, the elongation requirement for the alternative gage length shall be deemed not applicable.

98 **11.7** This specification does not provide requirements for product tension testing subsequent to shipment (see 15.1). Therefore, the requirements of 11.1 through 11.6 and Section 16 apply only for tests conducted at the place of manufacture prior to shipment. Compliance to Specification A 20/A 20M and the individual material specifications does not preclude the possibility that product tension test results may vary outside specified ranges. The tensile properties will vary within the same plate-as-rolled or piece, be it as-rolled, control-rolled, or heat-treated. The purchaser should, therefore, be aware that tension testing in accordance with the requirements of Specification A 20/A 20M does not provide assurance that all products of a plate-as-rolled will be identical in tensile properties with the products tested. If the purchaser wishes to have more confidence than that provided by Specification A 20/A 20M testing procedures, additional testing or requirements, such as Supplementary Requirement S4, should be imposed.

98 **11.7.1** Appendix X2 provides additional information on the variability of tensile properties in plates for pressure vessels.

12. Notch-Toughness Tests

12.1 *Charpy V-Notch Tests:*

12.1.1 *Number of Tests* — Except for plates subjected to quenching-and-tempering, and except as specified in 12.1.1.1 and 12.1.1.2, one impact test (3 specimens) for each specified orientation (see 12.1.2) shall be made from each plate-as-rolled. For plates subjected to quenching-and-tempering, one impact test shall be made from each plate-as-heat-treated.

12.1.1.1 *Plates Ordered Without the Heat Treatment Specified by the Material Specification* — When the material specification requires heat treatment but the plates are ordered without such heat treatment, and when Charpy V-notch tests are specified, one coupon shall be taken from each plate-as-rolled. The coupon shall be heat treated in accordance with the material specification and the purchase order and the plate qualified by specimens taken from the heat-treated coupon.

12.1.1.2 *Plates Produced from Coils* — When the plates are produced from coils and when Charpy V-notch tests are specified, the number of impact tests required shall be the same as the number specified in 11.1.1 for tension tests. The test coupons shall be taken from the material after flattening.

12.1.2 *Orientation of Test Specimens* — The long axes of the specimens shall be oriented either longitudinal (parallel to the final direction of rolling) or transverse (transverse to the final direction of rolling) as specified in the material specification or order.

12.1.3 *Location of Test Coupons* — The impact test coupons shall be taken adjacent to the tension test coupons. The impact test coupons shall be subject to the same requirements as those specified for tension tests in 11.4 except that the provisions of 11.4.3.1 apply to the area under the notch of the impact test specimen instead of to the gage length of the tension test specimen.

12.1.4 *Test Method* — Impact testing shall be performed in accordance with Test Methods and Definitions A 370 using Charpy V-notch (Type A) specimens as shown in Test Methods and Definitions A 370. Except as provided in 12.1.4.1, full-size (10 by 10 mm) specimens shall be used when the plate thickness permits, and their central axis shall correspond as near as practical to the $\frac{1}{4}$ *t* plane in the plate thickness *t*. Where the plate thickness is insufficient to obtain full-size specimens, sub-size specimens shall be used. The sub-size specimens may have a width of full material thickness or may be reduced in thickness to produce the largest possible standard sub-size specimen listed in Test Methods and Definitions A 370.

12.1.4.1 For materials that normally have absorbed energy values in excess of 180 ft·lbf [245 J] when tested using full-size specimens at the specified testing temperature, sub-size 0.4 by 0.268 in. [10 by 6.7 mm] specimens may be used in lieu of full-size specimens. However, when this option is used, the acceptance value shall be 75 ft·lbf [100 J] minimum for each specimen and the lateral expansion in mils [μm] shall be reported.

12.1.5 *Test Temperature* — The test temperature should be specified on the order. At the supplier's option, the actual test temperature may be lower than the specified test temperature. When a test temperature is not specified, tests shall be conducted at a temperature no higher than listed in Table A1.15 [A2.15] for the class, grade, and thickness of the material specified. The actual test temperature shall be reported with the test results.

12.1.6 *Acceptance Criteria* — Unless otherwise agreed upon, the acceptance criteria shall be as listed in Table A1.15 [A2.15] for the class, grade, and thickness of the material specified.

12.1.6.1 When the acceptance criteria is based on energy absorption of a full-size specimen, the acceptance criteria for the various sub-size specimens shall be as shown in Table A1.16 [A2.16] except as otherwise provided in 12.1.4.1.

12.1.6.2 When the acceptance criteria is based on lateral expansion opposite the notch, the acceptance value shall be the same for all sizes of specimens.

12.1.7 *Marking* — The letters "LTV" shall be stenciled or stamped on each plate following the class number, grade, etc.

12.1.8 *Variability* — The impact properties of steel can vary within the same plate-as-rolled or piece, be it as-rolled, control-rolled, or heat-treated. The purchaser should, therefore, be aware that testing of one plate-as-rolled does not provide assurance that all locations within a plate-as-rolled will be identical in toughness with the location tested. Normalizing or quenching and tempering the product will reduce the degree of variation. 98

12.1.8.1 Appendix X3 provides additional information on the variability of Charpy V-Notch test properties in plates for pressure vessels. 98

12.2 *Drop-Weight Tests:*

12.2.1 When specified, one drop-weight test, consisting of a set of two specimens, shall be made to the same frequency stated in 12.1.1 in accordance with Method E 208.

12.2.2 The test coupons shall be obtained adjacent to a tension test coupon. For plates produced from coils, the test coupon locations shall be the same as for Charpy V-notch tests. (See 12.1.) The provisions of 11.4 shall also apply.

12.2.3 The testing temperature shall be as specified in the material specification or order.

12.2.4 Acceptance shall be on the basis of *no-break* performance of both specimens at the specified testing temperature.

12.2.5 The plates shall be marked as required in 12.1.7 except that the letters "LTD" shall be used instead of "LTV."

13. Identification of Plates

13.1 Except as specified in 13.2, the name or brand of the manufacturer, heat and slab number, and specification number and grade, class and type, where indicated in the material specification, shall be legibly steel die stamped unless stenciling is specified by the purchaser on each finished plate in two places not less than 12 in. [300 mm] from the edges. The year-date of the specification to which the material is furnished need not be included in the marking. For plates produced from coils, the processor's identity shall be used rather than the identity of the manufacturer. Plates, the maximum lengthwise and crosswise dimensions of which do not exceed 72 in. [1800 mm], shall have the marking stamped in one place approximately midway between the center and an edge. The manufacturer's or processor's test identification number shall be legibly stamped on each test specimen.

13.1.1 Bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

13.2 For plates under $\frac{1}{4}$ in. [6 mm] in thickness, the marking specified in 13.1 shall be legibly stenciled instead of stamped.

98 **13.3** Plates that are required to be heat treated, but have not been so heat treated, shall be marked by the manufacturer with the letter "G" (denoting green) following the specification designation mark required by 13.1. Such plates shall have been qualified for shipment on the basis of test specimens that have been so heat treated. "G" marking is not required for such plates that are for shipment, for the purpose of obtaining the required heat treatment, to a processor under the manufacturer's control.

98 NOTE 1 — Any stress relief of test specimens intended to simulate post-weld heat treatment is not included in the above required heat treatment.

98 **13.4** Plates that are required to be heat treated, and have been so heat treated, shall be marked by the party that performed the heat treatment with the letters "MT" (denoting material treated) following the specification designation mark required by 13.1.

NOTE 2 — Any stress relief of test specimens intended to simulate post-weld heat treatment is not included in the above required heat treatment. 98

13.5 *Subdivided Material:*

13.5.1 Material separated from a master plate by a supplier shall be identified in accordance with the requirements of 13.1 through 13.4, except that the trademark, brand, or name of the organization subdividing the material shall be used, rather than the identity of the manufacturer.

13.5.2 By agreement between the purchaser and the supplier, a code traceable to the original required identification may be used to identify each piece of subdivided material, provided the trademark, brand, or name of the organization subdividing the material is also placed on the material and the original required identification, cross referenced to the code, is furnished with the material.

13.5.3 As an alternative, by agreement between the purchaser and the supplier, subdivided pieces from the same heat and slab of material may be bundled or placed in secured lifts and the identification specified in 13.5.1 shall then either be marked or stenciled on the top piece of each lift, or shown on a substantial tag attached to each lift or bundle.

13.5.4 For applications other than pressure vessels and by agreement between the purchaser and the supplier, another method of identifying and packaging the material may be used.

14. Permissible Variations in Dimensions or Mass

14.1 One cubic foot of rolled steel shall be assumed to weigh 490 lb, unless otherwise stated in the material specification. One cubic meter of rolled steel is assumed to have a mass of 7850 kg, unless otherwise stated in the material specification.

14.2 For carbon steel plates the permissible variations for dimensions shall not exceed the applicable limits stated in Annex A1, Tables A1.1 to A1.9, and Table A1.13 [Annex A2, Tables A2.1 to A2.9, and Table A2.13].

14.3 For alloy steel plates the permissible variations for dimensions shall not exceed the applicable limits stated in Annex A1, Tables A1.1 to A1.4, A1.8, and A1.10 to A1.13 [Annex A2, Tables A2.1 to A2.4, A2.8, and A2.10 to A2.13].

15. Inspection and Testing

15.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with the specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

15.2 When plates are produced from coils, 15.1 shall apply to the "processor" instead of to the "manufacturer" and the "place of process" shall apply instead of the "place of manufacture." When plates are produced from coils and the processor is different from the manufacturer, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered.

16. Retests

98 **16.1** *Tension Tests* — In addition to the provisions of Test Methods and Definitions A 370, the following retest provisions shall apply:

98 **16.1.1** If any test specimen shows defective machining, or develops flaws, it may be discarded and another specimen substituted.

98 **16.1.2** If the percentage of elongation of any tension test specimen is less than that specified, and any part of the fracture is more than $\frac{3}{4}$ in. [20 mm] from the center of the gage length of a 2 in. [50 mm] specimen or is outside the middle half of the gage length of an 8 in. [200 mm] specimen as indicated by scribe marks on the specimen before testing, one retest shall be allowed.

98 **16.1.3** If the results from an original tension test specimen fails to meet the specified requirements but are within 2 ksi [14 mPa] of the required tensile strength or within 1 ksi [7 mPa] of the required yield strength or yield point, or within 2% units of the required elongation or reduction in area, one retest shall be permitted to replace the failing test.

98 **16.1.4** The results of the retest shall meet the specified requirements.

16.2 *Charpy V-Notch Tests:*

16.2.1 The retest provisions of Test Methods and Definitions A 370 shall apply except that the 5 ft·lbf [7 J] absolute minimum for an individual specimen, as specified in Test Methods and Definitions A 370, does not apply when two thirds of the specified minimum average is less than 5 ft·lbf [7 J].

16.2.2 When Charpy V-notch impact test lateral expansion values are specified, if the value of one specimen falls below the specified minimum value and not below $\frac{2}{3}$ of the specified minimum value, and if the average of the three specimens equals or exceeds the specified minimum value, a retest of three additional specimens may be made. Each of the three retest specimens must equal or exceed the specified minimum value.

16.2.3 If the required values are not obtained on Charpy V-notch retests as specified in 16.2.1 and 16.2.2, or if the values in the initial test are below the values required for retest, no further retests are permitted unless the plate is heat treated or reheat treated. After heat treatment or reheat treatment, a set of three specimens shall be tested and each must equal or exceed the specified minimum value.

16.2.4 When the option of 12.1.4.1 is used and the test result falls below the 75 ft·lbf [100 J] minimum specified, another test may be made using full-size specimens.

17. Retreatment

17.1 If any heat-treated material fails to meet the mechanical requirements of the applicable specification, the material may be reheat treated. All mechanical property tests shall be repeated and the plate surface shall be reexamined for defects when the material is resubmitted for inspection.

18. Rejection

18.1 Any rejection based on product analysis made in accordance with the material specification shall be reported to the supplier and samples that represent the rejected material shall be preserved for 2 weeks from the date of notification of such rejection. In case of dissatisfaction with the results of the tests, the supplier may make claim for a rehearing within that time.

18.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's or processor's

works may be rejected. In such cases, the manufacturer or processor shall be notified.

19. Test Reports

19.1 The manufacturer or processor shall report the results of all tests required by the material specification, applicable supplementary requirements, and the order. Heat number and nominal plate thickness shall be shown on the test report. The year-date of the specification to which the material is furnished shall be included on the test report.

19.2 All heat treatment, exclusive of subcritical heating to soften thermally cut edges, shall be reported including temperature ranges and time at temperature. This exclusion does not apply to those materials with specified minimum tensile strengths of 95 ksi [655 MPa] or higher unless such subcritical heating is accomplished at temperatures at least 75°F [40°C] below the minimum tempering temperature. The reports shall state whether the plates only, the test specimens only, or both plates and test specimens were heat treated.

19.3 When Charpy V-notch tests are specified, the specimen size used shall be reported.

19.4 When required by the purchase order, the manufacturer shall also furnish a certification that the material has been manufactured and tested in accordance with the requirements of the material specification. For plates provided from coils, the processor shall furnish the required certification.

19.5 For plates produced from coils, both the manufacturer and processor shall be identified on the test report.

19.6 A signature is not required on the test report. However, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

19.7 Copies of the original manufacturer's test report shall be included with any subsequent test report.

19.8 A Material Test Report, Certificate of Inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report. 98

20. Packaging, Marking, and Loading for Shipment

20.1 Packaging, marking, and loading for shipment shall be in accordance with those procedures recommended by Practices A 700.

20.2 *For USA Government Procurement* — Packaging, packing, and marking of material for military procurement shall be in accordance with the requirements of MIL-STD-163, Level A, Level C, or commercial as specified in the contract or purchase order. Marking for shipment of material for civil agencies shall be in accordance with Fed. Std. No. 123.

21. Keywords 98

21.1 general delivery requirement; pressure containing parts; pressure vessel steels; steel plates; steel plates for pressure vessel applications

98

TABLE 1
LIMITS ON UNSPECIFIED ELEMENTS (SEE 7.1.1)

Copper, max %[A]	Heat analysis	0.40
	Product analysis	0.43
Nickel, max %[A]	Heat analysis	0.40
	Product analysis	0.43
Chromium, max %[A,B]	Heat analysis	0.30
	Product analysis	0.34
Molybdenum, max %[A,B]	Heat analysis	0.12
	Product analysis	0.13
Vanadium, max %[C]	Heat analysis	0.03
	Product analysis	0.04
Columbium, max %[C]	Heat analysis	0.02
	Product analysis	0.03

NOTES:

[A] The sum of copper, nickel, chromium, and molybdenum shall not exceed 1.00% on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining unspecified elements will apply.

[B] The sum of chromium and molybdenum shall not exceed 0.32% on heat anaylsis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining unspecified elements will apply.

[C] By agreement, the heat analysis limits for vanadium or columbium may be increased up to 0.10% and 0.05% on heat analysis and 0.11% and 0.06% on product analysis, respectively.

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser. Several of those that are considered suitable for use with each material specification are listed in the specification. Other tests may be performed by agreement between the supplier and the purchaser. These supplementary requirements shall apply only when specified in the order, in which event the specified tests shall be made by the supplier before shipment of the plates.

S1. Vacuum Treatment

S1.1 The steel shall be made by a process which includes vacuum degassing while molten. Unless otherwise agreed upon with the purchaser, it is the responsibility of the manufacturer to select suitable process procedures.

S2. Product Analysis

S2.1 A product analysis shall be made of each plate as rolled. The specimens for analysis shall be taken adjacent to or from a broken tension-test specimen.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

98 **S3.1** The test specimens representing the plate shall be thermally treated after the final heat treatment for mechanical properties to simulate heat treatments below the critical temperature that the plate may receive during fabrication after heat treatment for mechanical properties. The results of such test specimens shall represent the plate for purposes of acceptance. The temperature range, time, and cooling rates shall be as specified in the order.

S4. Additional Tension Test

S4.1 *Other Than Quenched-and-Tempered Plates* — In addition to the required single-tension test, a second tension test shall be made on a specimen taken from a corner of the plate-as-rolled on the end opposite the single specimen and in a direction parallel to the single specimen. The results obtained on testing this second specimen shall conform to the requirements of the specification.

S4.2 *Quenched-and-Tempered Plates 2 in. [50 mm] or Greater in Thickness* — In addition to the required tension tests, two additional specimens shall be taken from the bottom corner of the plate. One shall be taken at the center of the plate thickness and the other immediately beneath the surface. Mandatory conformance of these additional tests with specified properties shall be a matter of agreement between the manufacturer and the purchaser.

S4.3 For plates produced from coils, the additional tension test shall be taken immediately after the last plate produced to the qualifying specification.

S5. Charpy V-Notch Impact Test

S5.1 Charpy V-notch impact tests shall be conducted in accordance with 12.1.

S5.2 The orientation of the test bars, whether longitudinal or transverse to the direction of rolling, shall be as stated on the order.

S5.3 The test temperature and the required acceptance criteria, if other than those required in 12.1, shall be as stated on the order.

S5.4 The recorded results shall include test-bar orientation, specimen size, test temperature, absorbed energy values, and, when specified on the order for other than Class VI material, lateral expansion opposite the notch. The percent shear fracture appearance shall also be recorded when specified on the order.

S6. Drop-Weight Test (for Plates 0.625 in. [16 mm] and Over in Thickness)

S6.1 Drop-weight tests shall be made in accordance with the requirements of Test Method E 208. The specimens shall represent the plates in the final condition of heat treatment. Agreement shall be reached between the purchaser and the manufacturer or processor as to the number of plates to be tested and whether a

maximum NDT temperature is mandatory or if the test results are for information only.

S7. High-Temperature Tension Tests

S7.1 A short-time elevated temperature tension test shall be made to represent each plate or each heat of steel as indicated by the purchaser. The material for testing shall be obtained as required for the room temperature tension tests specified in the body of the specification. The hot tests shall be made in accordance with the requirements of Practice E 21. Mandatory conformance of these additional tests with specified properties shall be a matter for agreement between the manufacturer or processor and the purchaser.

S8. Ultrasonic Examination in Accordance with A 435/A 435M

S8.1 All plates shall be ultrasonically examined in accordance with the requirements of Specification A 435/A 435M.

S9. Magnetic Particle Examination

S9.1 All plate edges shall be examined by magnetic particles in accordance with the procedures covered in Practice E 709. The acceptability of defects revealed by this examination shall be judged in accordance with the requirements for quality in 9.3.

S10. Charpy V-Notch Impact Transition Curve

S10.1 Sufficient impact tests of the same specimen size shall be made from the plate test material to establish a transition curve. The test temperature range shall be wide enough to establish the upper and lower shelf energies, with sufficient testing at intermediate temperatures to permit plotting a reasonable smooth curve. A plot of the data is not required. The manufacturer shall report the specimen orientation, test temperature, and absorbed energy for each specimen tested. Lateral expansion and percent shear shall also be reported when specified in the order. The number of plates tested and the specimen orientation shall be the same as in 12.1 unless otherwise specified in the order.

S11. Ultrasonic Examination in Accordance with A 577/A 577M

S11.1 All plates shall be ultrasonically examined in accordance with the requirements of Specification A 577/A 577M.

S12. Ultrasonic Examination in Accordance with A 578/A 578M

S12.1 All plates shall be ultrasonically examined in accordance with the requirements of Specification A 578/A 578M. The acceptance level shall be as specified on the order.

S13. NDT Temperature Determination

S13.1 The NDT temperature shall be established in accordance with Method E 208 using coupons from a single plate. The number of plates to be so tested shall be subject to agreement between the purchaser and the manufacturer or processor.

S14. Bend Test

S14.1 Bend tests shall be performed with material in the condition prescribed by the individual specification. The frequency of testing shall be as agreed upon. The longitudinal axis of the test specimen shall be transverse to the final rolling direction of the plate. The test specimen shall be taken from the middle of a plate end. The width of the specimen shall be $1\frac{1}{4}$ to $1\frac{5}{8}$ in. [30 to 40 mm]. The specimen thickness shall be the full thickness of the material for plates $1\frac{1}{2}$ in. [40 mm] and under in thickness. For plates over $1\frac{1}{2}$ in. [40 mm] in thickness, the specimen thickness may be reduced to $1\frac{1}{2}$ in. [40 mm], but one surface shall be as rolled. When bent, the as-rolled surface shall be on the outer curve of the bend. The sides of the specimen may have the corners rounded to a radius of not more than $\frac{1}{16}$ in. [1.5 mm]. The bend test specimen shall withstand being bent cold through 180° without cracking on the outside of the bent portion, around a pin the diameter of which shall have a relation to the thickness of the specimen as prescribed in Table S14.1 for the individual material specification. If a bend test specimen fails due to conditions of bending more severe than required by the specification, a retest shall be permitted, either on a duplicate specimen or on a remaining portion of the failed specimen. If a sheared or gas-cut specimen fails due to conditions

associated with the sheared or gas-cut edges, a retest shall be permitted on a duplicate specimen with machined edges.

S15. Reduction of Area Measurement

S15.1 A reduction of area measurement shall be taken while making the required tension test. Reduction of area shall be determined only on the 0.500 in. [12.5 mm] round specimen as shown in Fig. 5 of Test Methods and Definitions A 370. The minimum acceptance limit shall be 40%.

S16. Thermal Stress Relief of Mechanical Test Coupons

S16.1 Test coupons representing the plates shall be thermally stress relieved by gradually and uniformly heating them to a temperature between 1100 and 1200°F [595 and 650°C], or a temperature range otherwise agreed upon between the manufacturer or processor and the purchaser, holding at temperature for at least 1 h/in. [2.4 min/mm] of thickness and cooling in still air to a temperature not exceeding 600°F [315°C].

S17. Vacuum Carbon-Deoxidized Steel

S17.1 Material shall be vacuum carbon-deoxidized, in which case the silicon content at the time of vacuum deoxidizing shall be 0.12% maximum, and the content of deoxidizers such as aluminum, zirconium, and titanium should be kept low enough to allow deoxidation by carbon. The test report shall indicate that the steel was vacuum carbon-deoxidized. The minimum heat analysis and product analysis requirements for silicon do not apply to vacuum carbon-deoxidized steel.

S19. Restricted Chemical Requirements

S19.1 Restricted heat analysis and product analysis limits are applicable as defined on the order.

S20. Maximum Carbon Equivalent for Weldability

S20.1 Plates shall be supplied with a specific maximum carbon equivalent value. This value shall be based on heat analysis. The required chemical analysis as well as the carbon equivalent shall be reported.

S20.2 The carbon equivalent shall be calculated using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S20.3. The maximum value of the carbon equivalent for carbon steels (including C-Mn, C-Mn-Si, C-Mn-Si-Al steels), are given in Table S20.1.

S21. Restricted Unspecified Elements

S21.1. The maximum limits on certain elements are 0.35% Cu, 0.25% Ni, 0.25% Cr, and 0.08% Mo on heat analysis. The sum of Cu, Ni, Cr, and Mo shall not exceed 0.70% on heat analysis.

S22. Through-Thickness Tension Tests

S22.1 Through-thickness tension tests shall be made in accordance with the requirements of Specification A 770/A 770M. (See Ordering Information in Specification A 770/A 770M for the additional information that may be needed.)

S24. Strain Age Test

S24.1 Test coupons shall be given a strain age treatment designated by the purchaser. Charpy V-notch tests shall be conducted on the strain aged specimens. Heat treatment, strain aging, test temperature, and acceptance criteria shall be as agreed upon between the manufacturer and purchaser.

S25. Weldability

S25.1 Weldability tests shall be conducted. The type of test and the acceptance criteria shall be as agreed upon between the manufacturer and purchaser.

S26. Low-Sulfur Steels

S26.1 The steel shall be made to 0.010% sulfur maximum. Lower sulfur levels and sulfide shape control practices can be specified by agreement between purchaser and supplier.

98 **S27. Restrictive Plate Flatness**

S27.1 Carbon steel plates, as-rolled or normalized, shall conform to the permissible restrictive variations from flatness as detailed in Table S27.1 or S27.1a.

S27.2 High-strength low-alloy steel plates, as-rolled or normalized, shall conform to the permissible restrictive variations from flatness as detailed in Table S27.2 or S27.2a.

TABLE S14.1
BEND DIAMETERS

Specification Designation	Grade, Type, or Class	Ratio of Pin Diameter to Specimen Thickness					
		Plate Thickness[A]					
		1 in. and under [25 mm and under]	Over 1 to 1½ in., incl [Over 25 to 40 mm, incl]	Over 1½ to 2 in., incl [Over 40 to 50 mm, incl]	Over 2 to 4 in., incl [Over 50 to 100 mm, incl]	Over 4 to 8 in., incl [Over 100 to 200 mm, incl]	Over 8 in. [Over 200 mm]
A 202	A	2	2½	3	...	...	...
	B	2½	3	3½	...	...	...
A 203	A	1	1½	1½	1½	2	...
	B	1½	2	2	2	2½	...
	D	1	1½	1½	1½	...	...
	E	1½	2	2	2	...	...
A 204	A	1	1½	1½	1½	2	...
	B	1½	2	2	2	2½	...
	C	2	2½	2½	3	3	...
A 225	A	1½	2	2	2	...	...
	B	2	2½	2½	3	...	...
A 285	Sheared or Gas-Cut	1	1½	2	...	...	...
	Universal-Mill	1½	2½	3	...	...	...
A 299	...	3	3½	4	4	4	...
A 302	A	2	2½	2½	3	3	3
	B	2½	3	3	3½	3½	3½
	C	2½	3	3	3½	3½	3½
	D	2½	3	3	3½	3½	3½
A 353	...	2[B]	2½[C]	3	...	...	...
A 387	2, 11, 12	1½	2	2	2	2½	2½
	5, 21, 22	2	2½	2½	3	3½	3½
A 442	55	1	1½	...	...	...	...
	60	1	1½	...	...	...	...
A 455	...	3	...	...	...	...	...

(*Continued*)

98

TABLE S14.1 (CONT'D)
BEND DIAMETERS

Specification Designation	Grade, Type, or Class	Ratio of Pin Diameter to Specimen Thickness — Plate Thickness[A]: 1 in. and under [25 mm and under]	Over 1 to 1½ in., incl [Over 25 to 40 mm, incl]	Over 1½ to 2 in., incl [Over 40 to 50 mm, incl]	Over 2 to 4 in., incl [Over 50 to 100 mm, incl]	Over 4 to 8 in., incl [Over 100 to 200 mm, incl]	Over 8 in. [Over 200 mm]
A 515	55	½	1	1	1½	2	2½
	60	1	1½	1½	2	2½	...
	65	1½	2	2	2	2½	...
	70	2	2	2	2½	3	...
A 516	55	½	1	1	1½	2	2½
	60	1	1½	1½	2	2½	...
	65	1½	2	2	2	2½	...
	70	2	2	2	2½	3	...
A 517	all	2	3	3	3	...	...
A 533	all	3½	3½	3½	3½	3½	3½
A 537	1	1½	1½[C]	2	2	...	...
	2	2	2[C]	2½	2½	...	...
A 542	all	3½	3½	3½	3½	3½	3½
A 543	all	3½	3½	3½	3½	3½	3½
A 553	all	2[B]	2½[C]	3	...	...	...
A 562	...	½	1	1½	...	...	...
A 612	...	2	...	...	...	...	...
A 645	...	2[B]	2½[C]	3	3	3	3
A 662	A	1½	1½	1½	...	...	...
	B	2	2	2	...	...	...
	C	2½	2½	2½	...	...	...
A 724	A	3	...	...	...	...	...
	B	3	...	...	...	...	...

NOTES:
[A] The listing of a bend test diameter ratio for a particular plate thickness is not intended to imply that plates of that thickness are available. See the individual material specification for applicable thickness limits for the various types and classes. Pin diameter-to-thickness ratios for thicker plates shall conform to the largest ratio shown in the table.
[B] ¾ in. [20 mm] and under.
[C] Over ¾ to 1¼ in. [20 to 32 mm] and under.

TABLE S20.1
MAXIMUM CARBON EQUIVALENT FOR WELDABILITY

Specified Minimum UTS	Maximum Carbon Equivalent Value	
ksi [MPa]	Thickness up to 2 in. [50 mm] incl	Thickness over 2 in. [50 mm]
60 ≤ UTS < 70 [415 ≤ UTS < 485]	0.45	0.46
70 ≤ UTS < 80 [485 ≤ UTS < 550]	0.47	0.48[A]
UTS ≥ 80 [UTS ≥ 550]	0.48[A,B]	. . .

NOTES:
[A] If simulated PWHT of the test coupons is specified (S3), the maximum carbon equivalent value may be increased up to 0.50 upon agreement between purchaser and supplier.
[B] Applicable to quenched-and-tempered material; for other conditions, maximum carbon equivalent shall be by agreement between purchaser and supplier.

98

TABLE S27.1
PERMISSIBLE VARIATIONS FROM FLATNESS FOR CARBON STEEL PLATES AS-ROLLED OR NORMALIZED ORDERED TO RESTRICTIVE FLATNESS

Note 1 — *Flatness Variations for Length* — The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

Note 2 — *Flatness Variations for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

Note 3 — When the longer dimension is under 36 in., the variation in flatness along the length and across the width shall not exceed 1/4 in. in each direction. When the longer dimension is from 36 to 72 in., inclusive, the permissible flatness variation shall not exceed 75% of the tabular amount for the specified width, but in no case less than 1/4 in.

Note 4 — The variations given in this table apply to plates that have a minimum specified tensile strength not over 60 ksi or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the permissible variations are 1 1/2 times the amounts shown in the table below.

Note 5 — This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

Note 6 — Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

Note 7 — A "Z" indicates that there is no published restricted value for the size.

Specified Thickness, in.	Permissible Variations from a Flat Surface for Specified Widths, in.					
	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, incl
To 1/4, excl	3/4	15/16	Z	Z	Z	Z
1/4 to 3/8, excl	9/16	3/4	7/8	15/16	1 1/16	1 1/8
3/8 to 1/2, excl	5/16	5/16	3/8	7/16	1/2	9/16
1/2 to 3/4, excl	5/16	5/16	5/16	3/8	1/2	1/2
3/4 to 1, excl	5/16	5/16	5/16	5/16	3/8	7/16
1 to 2, incl	1/4	5/16	5/16	5/16	5/16	3/8

98

TABLE S27.1a
PERMISSIBLE VARIATIONS FROM FLATNESS FOR CARBON STEEL PLATES AS-ROLLED OR NORMALIZED ORDERED TO RESTRICTIVE FLATNESS

Note 1 — *Flatness Variations for Length* — The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

Note 2 — *Flatness Variations for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

Note 3 — When the longer dimension is under 900 mm, the variation in flatness along the length and across the width shall not exceed 6 mm in each direction. When the longer dimension is from 900 to 1800 mm, inclusive, the permissible flatness variation shall not exceed 75% of the tabular amount for the specified width, but in no case less than 6 mm.

Note 4 — The variations given in this table apply to plates that have a minimum specified tensile strength not over 415 mpa or comparable chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the permissible variations are 1 1/2 times the amounts shown in the table below.

Note 5 — This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

Note 6 — Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

Note 7 — A "Z" indicates that there is no published restricted value for the size.

Specified Thickness, in.	Permissible Variations from a Flat Surface for Specified Widths, mm					
	1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, incl
To 6, excl	18	24	Z	Z	Z	Z
6 to 10, excl	15	18	22	24	27	29
10 to 12, excl	8	8	10	11	13	15
12 to 20, excl	7	8	8	10	13	13
20 to 25, excl	7	8	8	8	10	11
25 to 50, excl	7	7	7	8	8	8

TABLE S27.2 98
PERMISSIBLE VARIATIONS FROM FLATNESS FOR HIGH-STRENGTH LOW-ALLOY STEEL PLATES AS-ROLLED OR NORMALIZED ORDERED TO RESTRICTIVE FLATNESS

Note 1 — *Flatness Variations for Length* — The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

Note 2 — *Flatness Variations for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

Note 3 — When the longer dimension is under 36 in., the variation in flatness along the length and across the width shall not exceed $\frac{3}{8}$ in. in each direction. When the longer dimension is from 36 to 72 in., inclusive, the permissible flatness variation shall not exceed 75% of the tabular amount for the specified width, but in no case less than $\frac{3}{8}$ in.

Note 4 — This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

Note 5 — Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

Note 6 — A "Z" indicates that there is no published restricted value for the size.

Specified Thickness, in.	Permissible Variations from a Flat Surface for Specified Widths, in.					
	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, incl
To $\frac{1}{4}$, excl	$1\frac{1}{16}$	$1\frac{7}{16}$	Z	Z	Z	Z
$\frac{1}{4}$ to $\frac{3}{8}$, excl	$\frac{7}{8}$	$1\frac{1}{16}$	$1\frac{5}{16}$	$1\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{11}{16}$
$\frac{3}{8}$ to $\frac{1}{2}$, excl	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$
$\frac{1}{2}$ to $\frac{3}{4}$, excl	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$
$\frac{3}{4}$ to 1, excl	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{11}{16}$
1 to 2, incl	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$

TABLE S27.2a 98
PERMISSIBLE VARIATIONS FROM FLATNESS FOR HIGH-STRENGTH LOW-ALLOY STEEL PLATES AS-ROLLED OR NORMALIZED ORDERED TO RESTRICTIVE FLATNESS

Note 1 — *Flatness Variations for Length* — The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 3700 mm in length, or in any 3700 mm of longer plates.

Note 2 — *Flatness Variations for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

Note 3 — When the longer dimension is under 900 mm, the variation in flatness along the length and across the width shall not exceed 10 mm in each direction. When the longer dimension is from 900 to 1800 mm, inclusive, the permissible flatness variation shall not exceed 75% of the tabular amount for the specified width, but in no case less than 10 mm.

Note 4 — This table and these notes cover the flatness variations of circular and sketch plates based on the maximum dimensions of those plates.

Note 5 — Waviness tolerances for rectangular plates, universal mill plates, and circular and sketch plates do not apply.

Note 6 — A "Z" indicates that there is no published restricted value for the size.

Specified Thickness, in.	Permissible Variations from a Flat Surface for Specified Widths, mm					
	1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, incl
To 6, excl	27	36	Z	Z	Z	Z
6 to 10, excl	22	27	33	36	39	43
10 to 12, excl	12	12	15	17	19	21
12 to 20, excl	11	11	13	15	16	18
20 to 25, excl	11	11	12	13	15	17
25 to 50, excl	10	11	11	12	13	13

ANNEXES

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC. — INCH-POUND UNITS

A1.1 Listed below are permissible variations in dimensions, and notch toughness information, expressed in inch-pound units of measurement.

TABLE A1.1
PERMISSIBLE VARIATIONS IN THICKNESS FOR RECTANGULAR PLATES

Specified Thickness, in.	Tolerance Over Specified Thickness for Widths Given, in.											
	48 and under	Over 48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 132, excl	132 to 144, excl	144 to 168, excl	168 to 182, excl	182 and over
To 1/4, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	...	...	...
1/4 to 5/16, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	...	...	...
5/16 to 3/8, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	...	...
3/8 to 7/16, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
7/16 to 1/2, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.06	...
1/2 to 5/8, excl	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06	0.07	...
5/8 to 3/4, excl	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.07	0.07
3/4 to 1, excl	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.07	0.08	0.09
1 to 2, excl	0.06	0.06	0.06	0.06	0.06	0.07	0.08	0.10	0.10	0.11	0.13	0.16
2 to 3, excl	0.09	0.09	0.09	0.10	0.10	0.11	0.12	0.13	0.14	0.15	0.15	...
3 to 4, excl	0.11	0.11	0.11	0.11	0.11	0.13	0.14	0.14	0.14	0.15	0.17	...
4 to 6, excl	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.20	0.20	...
6 to 10, excl	0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.27	0.28	...
10 to 12, excl	0.29	0.29	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.35	...
12 to 15, incl	0.29	0.29	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	...

NOTES:
(1) Permissible variation under specified thickness, 0.01 in.
(2) Thickness to be measured at 3/8 to 3/4 in. from the longitudinal edge.
(3) For thickness measured at any location other than that specified in Note 2, the permissible maximum over-tolerance shall be increased by 75%, rounded to the nearest 0.01 in.

98

TABLE A1.2
PERMISSIBLE VARIATIONS OVER IN WIDTH AND LENGTH FOR SHEARED PLATES (NOTE 1) AND LENGTH ONLY FOR UNIVERSAL MILL PLATES (NOTE 2)

Note 1 — Carbon steel and high-strength low-alloy steel plates 1½ in. and under in thickness. Alloy steel plates 1¼ in. and under in thickness.
Note 2 — Carbon steel and high-strength low-alloy steel plates 2½ in. and under in thickness. Alloy steel plates 2 in. and under in thickness.
Note 3 — Permissible variation under specified width and length: ¼ in.

Specified Dimensions, in.		Variations over Specified Width and Length for Thicknessses, in., Given							
		To 3/8, excl		3/8 to 5/8, excl		5/8 to 1, excl		1 to 2, incl[A]	
Length	Width	Width	Length	Width	Length	Width	Length	Width	Length
To 120, excl	over 8 to 60, excl	3/8	1/2	7/16	5/8	1/2	3/4	5/8	1
	60 to 84, excl	7/16	5/8	1/2	11/16	5/8	7/8	3/4	1
	84 to 108, excl	1/2	3/4	5/8	7/8	3/4	1	1	1 1/8
	108 and over	5/8	7/8	3/4	1	7/8	1 1/8	1 1/8	1 1/4
120 to 240, excl	over 8 to 60, excl	3/8	3/4	1/2	7/8	5/8	1	3/4	1 1/8
	60 to 84, excl	1/2	3/4	5/8	7/8	3/4	1	7/8	1 1/4
	84 to 108, excl	9/16	7/8	11/16	15/16	13/16	1 1/8	1	1 3/8
	108 and over	5/8	1	3/4	1 1/8	7/8	1 1/4	1 1/8	1 3/8
240 to 360, excl	over 8 to 60, excl	3/8	1	1/2	1 1/8	5/8	1 1/4	3/4	1 1/2
	60 to 84, excl	1/2	1	5/8	1 1/8	3/4	1 1/4	7/8	1 1/2
	84 to 108, excl	9/16	1	11/16	1 1/8	7/8	1 3/8	1	1 1/2
	108 and over	11/16	1 1/8	7/8	1 1/4	1	1 3/8	1 1/4	1 3/4
360 to 480, excl	over 8 to 60, excl	7/16	1 1/8	1/2	1 1/4	5/8	1 3/8	3/4	1 5/8
	60 to 84, excl	1/2	1 1/4	5/8	1 3/8	3/4	1 1/2	7/8	1 5/8
	84 to 108, excl	9/16	1 1/4	3/4	1 3/8	7/8	1 1/2	1	1 7/8
	108 and over	3/4	1 3/8	7/8	1 1/2	1	1 5/8	1 1/4	1 7/8
480 to 600, excl	over 8 to 60, excl	7/16	1 1/4	1/2	1 1/2	5/8	1 5/8	3/4	1 7/8
	60 to 84, excl	1/2	1 3/8	5/8	1 1/2	3/4	1 5/8	7/8	1 7/8
	84 to 108, excl	5/8	1 3/8	3/4	1 1/2	7/8	1 5/8	1	1 7/8
	108 and over	3/4	1 1/2	7/8	1 5/8	1	1 3/4	1 1/4	1 7/8
600 to 720, excl	over 8 to 60, excl	1/2	1 3/4	5/8	1 7/8	3/4	1 7/8	7/8	2 1/4
	60 to 84, excl	5/8	1 3/4	3/4	1 7/8	7/8	1 7/8	1	2 1/4
	84 to 108, excl	5/8	1 3/4	3/4	1 7/8	7/8	1 7/8	1 1/8	2 1/4
	108 and over	7/8	1 3/4	1	2	1 1/8	2 1/4	1 1/4	2 1/2
720 and over	over 8 to 60, excl	9/16	2	3/4	2 1/8	7/8	2 1/4	1	2 3/4
	60 to 84, excl	3/4	2	7/8	2 1/8	1	2 1/4	1 1/8	2 3/4
	84 to 108, excl	3/4	2	7/8	2 1/8	1	2 1/4	1 1/4	2 3/4
	108 and over	1	2	1 1/8	2 3/8	1 1/4	2 1/2	1 3/8	3

[A] Permissible variations in length apply also to carbon-steel and High-Strength Low-Alloy Steel Universal Mill plates up to 12 in. in width for thicknesses over 2 to 2½ in., incl.

TABLE A1.3
PERMISSIBLE VARIATIONS IN ROLLED WIDTH FOR UNIVERSAL MILL CARBON-STEEL, HIGH-STRENGTH LOW-ALLOY STEEL AND ALLOY-STEEL PLATES 15 IN. AND UNDER IN THICKNESS

	Variations Over Specified Width for Thicknesses Given, in.					
Specified Width, in.	To 3/8, excl	3/8 to 5/8, excl	5/8 to 1, excl	1 to 25 incl	Over 2 to 10, incl	Over 10 to 15, incl
Over 8 to 20, excl	1/8	1/8	3/16	1/4	3/8	1/2
20 to 36, excl	3/16	1/4	5/16	3/8	7/16	9/16
36 and over	5/16	3/8	7/16	1/2	9/16	5/8

GENERAL NOTE: Permissible variation under specified width shall be 1/8 in.

TABLE A1.4
PERMISSIBLE VARIATIONS IN DIAMETER FOR SHEARED CIRCULAR CARBON-STEEL, HIGH-STRENGTH LOW-ALLOY STEEL AND ALLOY-STEEL PLATES 1 IN. AND UNDER IN THICKNESS

	Permissible Variations Over Specified Diameter for Thicknesses Given, in.		
Specified Diameter, in.	To 3/8, excl	3/8 to 5/8, excl	5/8 to 1, incl
To 32, excl	1/4	3/8	1/2
32 to 84, excl	5/16	7/16	9/16
84 to 108, excl	3/8	1/2	5/8
108 to 130, incl	7/16	9/16	11/16

GENERAL NOTE: No permissible variations under specified diameter.

TABLE A1.5
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR RECTANGULAR CARBON-STEEL AND HIGH-STRENGTH LOW-ALLOY STEEL PLATES WHEN GAS CUTTING IS SPECIFIED OR REQUIRED

Specified Thickness, in.	Variations Over for All Specified Widths or Lengths, in.
To 2, excl	1/2
2 to 4, excl	5/8
4 to 6, excl	3/4
6 to 8, excl	7/8
8 to 15, incl	1

NOTES:
(1) These variations may be taken all under or divided over and under, if so specified.
(2) Plates with universal rolled edges will be gas cut to length only.

TABLE A1.6
PERMISSIBLE VARIATIONS IN DIAMETER FOR GAS-CUT CIRCULAR CARBON-STEEL AND HIGH-STRENGTH LOW-ALLOY STEEL PLATES

Specified Diameter, in.	Variations Over Specified Diameter for Thicknesses Given, in.					
	To 1, excl	1 to 2, excl	2 to 4, excl	4 to 6, excl	6 to 8, excl	8 to 15, incl
To 32, excl	3/8	3/8	1/2	1/2	5/8	3/4
32 to 84, excl	3/8	1/2	1/2	5/8	3/4	7/8
84 to 108, excl	1/2	9/16	5/8	3/4	7/8	1
108 to 130, excl	1/2	9/16	11/16	7/8	1	1 1/8
130 and over	5/8	3/4	7/8	1	1 1/8	1 1/4

GENERAL NOTE: No permissible variations under specified diameter.

TABLE A1.7
PERMISSIBLE CAMBER FOR CARBON STEEL SHEARED OR GAS-CUT RECTANGULAR PLATES ALL THICKNESSES

Maximum permissible camber, in. = 1/8 in. × (number of feet of length/5)

GENERAL NOTE: Camber, as it relates to plates, is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE A1.8
PERMISSIBLE CAMBER FOR CARBON STEEL, HIGH-STRENGTH LOW-ALLOY STEEL AND ALLOY STEEL UNIVERSAL MILL PLATES AND HIGH-STRENGTH LOW-ALLOY STEEL AND ALLOY STEEL SHEARED OR GAS-CUT RECTANGULAR PLATES

Dimension, in.		Camber for Thickness and Widths Given
Thickness	Width	
To 2, incl	all	1/8 in. × (number of feet of length/5)
Over 2 to 15, incl	to 30, incl	3/16 in. × (number of feet of length/5)
Over 2 to 15, incl	over 30	1/4 in. × (number of feet of length/5)

TABLE A1.9
PERMISSIBLE VARIATIONS FROM FLATNESS FOR CARBON-STEEL PLATES

Specified Thickness, in.	Variations from a Flat Surface for Specified Widths, in.										
	Over 8 to 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 and over
To 1/4, excl	9/16	3/4	15/16	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	...	...
1/4 to 3/8, excl	1/2	5/8	3/4	15/16	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	...	...
3/8 to 1/2, excl	1/2	9/16	5/8	5/8	3/4	7/8	1	1 1/8	1 1/4	1 7/8	2 1/8
1/2 to 3/4, excl	7/16	1/2	9/16	5/8	5/8	3/4	1	1	1 1/8	1 1/2	2
3/4 to 1, excl	7/16	1/2	9/16	5/8	5/8	5/8	3/4	7/8	1	1 3/8	1 3/4
1 to 2, excl	3/8	1/2	1/2	9/16	9/16	5/8	5/8	5/8	11/16	1 1/8	1 1/2
2 to 4, excl	5/16	3/8	7/16	1/2	1/2	1/2	1/2	9/16	5/8	7/8	1 1/8
4 to 6, excl	3/8	7/16	1/2	1/2	9/16	9/16	5/8	3/4	7/8	7/8	1
6 to 8, excl	7/16	1/2	1/2	5/8	11/16	3/4	7/8	7/8	1	1	1
8 to 10, excl	1/2	1/2	5/8	11/16	3/4	13/16	7/8	15/16	1	1	1
10 to 12, excl	1/2	5/8	3/4	13/16	7/8	15/16	1	1	1	1	1
12 to 15, incl	5/8	3/4	13/16	7/8	15/16	1	1	1	1	1	...

GENERAL NOTES:

(A) *Flatness Variations for Length* — The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

(B) *Flatness Variations for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

(C) When the longer dimension is under 36 in., the variation in flatness along the length and across the width shall not exceed 1/4 in. in each direction. When the longer dimension is from 36 to 72 in., inclusive, the flatness variation shall not exceed 75% of the tabular amount for the specified width, but in no case less than 1/4 in.

(D) The tolerances given in this table apply to plates that have a minimum specified tensile strength not over 60 000 psi or compatible chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the limits given in the table are increased to 1 1/2 times the amounts in the above table.

(E) This table and notes cover the flatness tolerances of circular and sketch plates, based on the maximum dimensions of those plates.

TABLE A1.10
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR RECTANGULAR ALLOY-STEEL PLATES WHEN GAS CUTTING IS SPECIFIED OR REQUIRED

Specified Thickness, in.	Variations Over for All Specified Widths and Lengths, in.
To 2, excl	3/4
2 to 4, excl	1
4 to 6, excl	1 1/8
6 to 8, excl	1 5/16
8 to 15, incl	1 1/2

NOTES:
(1) These variations may be taken all under or divided over and under, if specified.
(2) Plates with universal rolled edges will be gas cut to length only.

TABLE A1.11
PERMISSIBLE VARIATIONS IN DIAMETER FOR GAS-CUT CIRCULAR ALLOY-STEEL PLATES

	Variations Over Specified Diameter for Thicknesses Given, in.					
Specified Diameter, in.	To 1, excl	1 to 2, excl	2 to 4, excl	4 to 6, excl	6 to 8, excl	8 to 15, incl
To 32, excl	1/2	3/4	3/4	3/4	1	1
32 to 84, excl	1/2	5/8	7/8	1	1 1/8	1 1/4
84 to 108, excl	5/8	3/4	1	1 1/8	1 1/4	1 3/8
108 to 130, incl	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2

GENERAL NOTE: No permissible variations under specified diameter.

TABLE A1.12
PERMISSIBLE VARIATIONS FROM FLATNESS FOR HIGH-STRENGTH LOW-ALLOY AND ALLOY-STEEL PLATES

Specified Thickness, in.	Variations from a Flat Surface for Specified Widths, in.										
	Over 8 to 36, excl	36 to 48, excl	48 to 60, excl	60 to 72, excl	72 to 84, excl	84 to 96, excl	96 to 108, excl	108 to 120, excl	120 to 144, excl	144 to 168, excl	168 and over
To 1/4, excl	13/16	1 1/8	1 3/8	1 7/8	2	2 1/4	2 3/8	2 5/8	2 3/4	...	...
1/4 to 3/8, excl	3/4	15/16	1 1/8	1 3/8	1 3/4	1 7/8	2	2 1/4	2 3/8	...	...
3/8 to 1/2, excl	3/4	7/8	15/16	15/16	1 1/8	1 5/16	1 1/2	1 5/8	1 7/8	2 3/4	3 1/8
1/2 to 3/4, excl	5/8	3/4	13/16	7/8	1	1 1/8	1 1/4	1 3/8	1 5/8	2 1/4	3
3/4 to 1, excl	5/8	3/4	7/8	7/8	15/16	1	1 1/8	1 5/16	1 1/2	2	2 5/8
1 to 2, excl	9/16	5/8	3/4	13/16	7/8	15/16	1	1	1	1 5/8	2 1/4
2 to 4, excl	1/2	9/16	11/16	3/4	3/4	3/4	3/4	7/8	1	1 1/4	1 5/8
4 to 6, excl	9/16	11/16	3/4	3/4	7/8	7/8	15/16	1 1/8	1 1/4	1 1/4	1 1/2
6 to 8, excl	5/8	3/4	3/4	15/16	1	1 1/8	1 1/4	1 5/16	1 1/2	1 1/2	1 1/2
8 to 10, excl	3/4	13/16	15/16	1	1 1/8	1 1/4	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2
10 to 12, excl	3/4	15/16	1 1/8	1/4	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2
12 to 15, incl	7/8	1	1 3/16	1 5/16	1 3/8	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2

NOTES:

(1) *Flatness Tolerances for Length* — The longer dimension specified is considered the length and variations from a flat surface along the length shall not exceed tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft of longer plates.

(2) *Flatness Tolerances for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.

(3) When the longer dimension is under 36 in., the variation shall not exceed 3/8 in. When the larger dimension is from 36 to 72 in., incl, the variation shall not exceed 75% of the tabular amount for the specified width.

(4) This table and notes cover the tolerances for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

TABLE A1.13
WAVINESS TOLERANCES FOR RECTANGULAR PLATES, UNIVERSAL MILL PLATES, AND CIRCULAR AND SKETCH PLATES

Flatness Tolerance from Tables A1.9 and A1.12	When Number of Waves in 12 ft is:						
	1	2	3	4	5	6	7
5/16	5/16	1/4	3/16	1/8	1/8	1/16	1/16
3/8	3/8	5/16	3/16	3/16	1/8	1/16	1/16
7/16	7/16	5/16	1/4	3/16	1/8	1/8	1/16
1/2	1/2	3/8	5/16	3/16	3/16	1/8	1/16
9/16	9/16	7/16	5/16	1/4	3/16	1/8	1/8
5/8	5/8	1/2	3/8	1/4	3/16	1/8	1/8
11/16	11/16	1/2	3/8	5/16	3/16	3/16	1/8
3/4	3/4	9/16	7/16	5/16	1/4	3/16	1/8
13/16	13/16	5/8	7/16	5/16	1/4	3/16	1/8
7/8	7/8	11/16	1/2	3/8	1/4	3/16	1/8
15/16	15/16	11/16	1/2	3/8	5/16	1/4	3/16
1	1	3/4	9/16	7/16	5/16	1/4	3/16
1 1/8	1 1/8	7/8	5/8	1/2	3/8	1/4	3/16
1 1/4	1 1/4	15/16	11/16	1/2	3/8	5/16	1/4
1 3/8	1 3/8	1 1/16	3/4	9/16	7/16	5/16	1/4
1 1/2	1 1/2	1 1/8	7/8	5/8	1/2	3/8	1/4
1 5/8	1 5/8	1 1/4	15/16	11/16	1/2	3/8	5/16
1 3/4	1 3/4	1 5/16	1	3/4	9/16	7/16	5/16
1 7/8	1 7/8	1 7/16	1 1/16	13/16	9/16	7/16	5/16
2	2	1 1/2	1 1/8	7/8	5/8	1/2	3/8
2 1/8	2 1/8	1 5/8	1 3/16	7/8	11/16	1/2	3/8
2 1/4	2 1/4	1 11/16	1 1/4	15/16	11/16	9/16	3/8
2 3/8	2 3/8	1 13/16	1 5/16	1	3/4	9/16	7/16
2 1/2	2 1/2	1 7/8	1 7/16	1 1/16	13/16	9/16	7/16
2 5/8	2 5/8	2	1 1/2	1 1/8	13/16	5/8	7/16
2 3/4	2 3/4	2 1/16	1 9/16	1 1/8	7/8	5/8	1/2
2 7/8	2 7/8	2 3/16	1 5/8	1 3/16	15/16	11/16	1/2
3	3	2 1/4	1 11/16	1 1/4	15/16	11/16	9/16
3 1/8	3 1/8	2 3/8	1 3/4	1 5/16	1	3/4	9/16

GENERAL NOTE: Waviness denotes the deviation of the top or bottom surface from a horizontal line, when the plate is resting on a flat surface, as measured in an increment of less than 12 ft of length. The waviness tolerance is a function of the flatness tolerance as obtained from Tables A1.9 and A1.12.

TABLE A1.14
VISIBLE EDGE INDICATIONS EXTENDING APPROXIMATELY PARALLEL TO ROLLED SURFACES

Plate Specification and Thickness	Acceptable		Remove by Grinding		Acceptable on Edges Cut in Fabrication	
	Depth	Length[B]	Depth	Length[B]	Depth	Length[B]
Column	1	2	3	4	5	6
Nonkilled,[A] to 2 in., incl	1/8 in. max	any	over 1/8 in. to 1/4 in., incl	over 1 in.	1/4 in. max	any
Killed,[C] to 6 in., incl	1/16 in. max	any	over 1/16 in. to 1/8 in., incl	over 1 in.	1/8 in. max	any
Killed,[C] over 6 in.	1/8 in. max	any	over 1/8 in. to 1/2 in., incl	over 1 in.	1/2 in. max	any

NOTES:
[A] Specifications: A 285; A 433; A 442 in thicknesses to 1 in., incl; or A 455.
[B] Laminar-type discontinuities 1 in. and less in length are acceptable and do not require exploration.
[C] The specification in 1.1 of the Scope, of this standard other than those listed in the above footnote *A*.

TABLE A1.15
GENERALLY AVAILABLE GRADE-THICKNESS-MINIMUM TEST TEMPERATURE COMBINATIONS MEETING CHARPY V-NOTCH REQUIREMENTS INDICATED (NORMALIZED OR QUENCHED AND TEMPERED CONDITION)

Acceptance Criteria Charpy V-Notch Energy Absorption				Test Temperature, °F for Plate Thicknesses (Unless Otherwise Agreed Upon)			
Class[A]	Average For 3 Specimens[C] ft-lbf, min	Minimum For 1 Specimen[C] ft-lbf	Specification and Grade[B]	1 in. and Under	Over 1 in. to 2 in., incl.	Over 2 in. to 3 in., incl.	Over 3 in. to 5 in., incl.
I	10	7	A 285 Grade A	+40	+60	...	...
			A 285 Grade B	+50	+70	...	...
			A 285 Grade C	+60	+80	...	...
			A 442 Grade 55	+30	...	...	...
			A 442 Grade 60	+35	...	...	...
II	13	10	A 455	+25	...	...	...
III	13	10	A 203 Grade A	−90	−90	−75	...
			A 203 Grade D	−150	−150	−125	...
			A 442 Grade 55 (1½ in. max thickness)	...	−20	...	...
			A 442 Grade 60 (1½ in. max thickness)	...	−15	...	...
			A 516 Grade 55	−60	−60	−50	−50
			A 516 Grade 60	−60	−50	−50	−50
			A 516 Grade 65	−60	−50	−40	−25
			A 537 Class 1 (Over 2½–4 in.)	...	...	−75	−50
			A 662 Grade A	−75	−75	...	...
			A 662 Grade B	−60	−60	...	...
IV	15	12	A 203 Grade B	−90	−90	−75	...
			A 203 Grade E	−150	−150	−125	...
			A 203 Grade F (4 in. max)	...	...	−160	−160
			A 299	+20	+30	+30	+40
			A 516 Grade 70	−50	−40	−30	−20
			A 537 Class 1 (2½ in. max)	−80	−75	−75	...
			A 537 Class 2 (Over 2½–4 in.)	...	...	−75	−50
			A 662 Grade C	−50	−50	...	...

(Continued)

TABLE A1.15 (CONT'D)
GENERALLY AVAILABLE GRADE-THICKNESS-MINIMUM TEST TEMPERATURE COMBINATIONS MEETING CHARPY V-NOTCH REQUIREMENTS INDICATED (NORMALIZED OR QUENCHED AND TEMPERED CONDITION)

Acceptance Criteria Charpy V-Notch Energy Absorption				Test Temperature, °F for Plate Thicknesses (Unless Otherwise Agreed Upon)			
Class[A]	Average For 3 Specimens[C] ft-lbf, min	Minimum For 1 Specimen[C] ft-lbf	Specification and Grade[B]	1 in. and Under	Over 1 in. to 2 in., incl.	Over 2 in. to 3 in., incl.	Over 3 in. to 5 in., incl.
V	20	15	A 203 Grade F	−160	−160	...	...
			A 537 Class 2 (2½ in. max)	−90	−90	−90	...
			A 612	−50	...	...	...
			A 724 Grade A	−50	...	...	...
	Lateral Expansion Mils. Minimum Each Specimen Transverse Test						
VI		15	A 353	−320	−320	...	...
			A 553 Type I	−320	−320	...	...
			A 553 Type II	−275	−275	...	...
			A 645	−275	−275	...	...
			A 517 all (2½ in. max thickness)	[B]	[B]	...	...
			A 724 Grade B	−50	...	...	...

NOTES:
[A] Class I is *Other Than Fully Killed* with a specified minimum tensile strength of 65 ksi or lower.
Class II is *Other Than Fully Killed* with a specified minimum tensile strength of over 65 ksi to 75 ksi.
Class III is *Fully Killed* with a specified minimum tensile strength of 65 ksi or lower.
Class IV is *Fully Killed* with a specified minimum tensile strength of over 65 ksi to 75 ksi.
Class V is *Fully Killed* with a specified minimum tensile strength of over 75 ksi to but not including 95 ksi.
Class VI is *Fully Killed* with a specified minimum tensile strength of 95 ksi and over.
[B] Testing temperature as specified on order but no higher than 32°F.
[C] Full size (10 by 10 mm) specimens.

98

TABLE A1.16
CHARPY V-NOTCH TEST ACCEPTANCE CRITERIA FOR VARIOUS SUB-SIZE SPECIMENS[A]

Full Size, 10 by 10 mm		¾ Size, 10 by 7.5 mm		⅔ Size, 10 by 6.7 mm		½ Size, 10 by 5 mm		⅓ Size, 10 by 3.3 mm		¼ Size, 10 by 2.5 mm	
ft-lbf	[J]	ft-lbf	[J]	ft-lbf	[J]	ft-lbf	[J]	ft-lbf	[J]	ft-lbf	[J]
40	[54]	30	[41]	27	[37]	20	[27]	13	[18]	10	[14]
35	[48]	26	[35]	23	[31]	18	[24]	12	[16]	9	[12]
30	[41]	22	[30]	20	[27]	15	[20]	10	[14]	8	[11]
25	[34]	19	[26]	17	[23]	12	[16]	8	[11]	6	[8]
20	[27]	15	[20]	13	[18]	10	[14]	7	[10]	5	[7]
16	[22]	12	[16]	11	[15]	8	[11]	5	[7]	4	[5]
15	[20]	11	[15]	10	[14]	8	[11]	5	[7]	4	[5]
13	[18]	10	[14]	9	[12]	6	[8]	4	[5]	3	[4]
12	[16]	9	[12]	8	[11]	6	[8]	4	[5]	3	[4]
10	[14]	8	[11]	7	[10]	5	[7]	3	[4]	2	[3]
7	[10]	5	[7]	5	[7]	4	[5]	2	[3]	2	[3]

GENERAL NOTE: [A] Interpretation shall be made for specimens with widths intermediate of those listed. Interpolated values shall be rounded to the nearest whole number as prescribed in Practice E 29.

TABLE A1.17
PERMISSIBLE VARIATIONS IN WIDTH FOR MILL EDGE CARBON STEEL AND HIGH-STRENGTH LOW-ALLOY STEEL PLATES PRODUCED ON STRIP MILLS

Specified Width, in.	Variations over Specified Width, in[A]
To 14, excl	7/16
14 to 17, excl	1/2
17 to 19, excl	9/16
19 to 21, excl	5/8
21 to 24, excl	11/16
24 to 26, excl	13/16
26 to 28, excl	15/16
28 to 35, excl	1 1/8
35 to 50, excl	1 1/4
50 to 60, excl	1 1/2
60 to 65, excl	1 5/8
65 to 70, excl	1 3/4
70 to 80, excl	1 7/8
80 and over	2

NOTE:
[A] No permissible variation under specified width.

TABLE A2.1
PERMISSIBLE VARIATIONS IN THICKNESS FOR RECTANGULAR PLATES

Specified Thickness, mm	Tolerance Over Specified Thickness for Widths Given in Millimetres, mm										
	1200 and Under	Over 1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, excl	3000 to 3300, excl	3300 to 3600, excl	3600 to 4200, excl	4200 and Over
5.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	. . .	. . .
5.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.4	. . .
6.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.1	1.4	. . .
7.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.5	1.7
8.0	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.5	1.7
9.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.8
10.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.8
11.0	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.3	1.5	1.8
12.0	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.0	1.3	1.5	2.0
14.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.6	2.0
16.0	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.6	2.0
18.0	0.8	0.8	0.8	0.8	0.9	1.0	1.1	1.2	1.4	1.8	2.2
20.0	0.8	0.8	0.8	0.8	0.9	1.0	1.2	1.2	1.4	1.8	2.2
22.0	0.8	0.9	0.9	0.9	1.0	1.1	1.3	1.3	1.5	2.0	2.4
25.0	0.9	0.9	1.0	1.0	1.0	1.2	1.3	1.5	1.5	2.1	2.6
28.0	1.0	1.0	1.1	1.1	1.1	1.3	1.4	1.8	1.8	2.3	2.8
30.0	1.1	1.1	1.2	1.2	1.2	1.4	1.5	1.8	1.8	2.5	3.0
32.0	1.2	1.2	1.3	1.3	1.3	1.5	1.6	2.0	2.0	2.7	3.3
35.0	1.3	1.3	1.4	1.4	1.4	1.6	1.7	2.3	2.3	2.8	3.5
38.0	1.4	1.4	1.5	1.5	1.5	1.7	1.8	2.3	2.3	3.0	3.8
40.0	1.5	1.5	1.6	1.6	1.6	1.8	2.0	2.5	2.5	3.3	3.8
45.0	1.6	1.6	1.7	1.8	1.8	2.0	2.3	2.8	2.8	3.5	4.0
50.0	1.8	1.8	1.8	2.0	2.0	2.3	2.5	3.0	3.0	3.8	4.0
55.0	2.0	2.0	2.0	2.2	2.2	2.5	2.8	3.3	3.3	4.0	4.0
60.0	2.3	2.3	2.3	2.4	2.4	2.8	3.0	3.4	3.4	4.0	4.4
70.0	2.5	2.5	2.5	2.6	2.6	3.0	3.3	3.5	3.6	4.0	4.4
80.0	2.8	2.8	2.8	2.8	2.8	3.3	3.5	3.5	3.6	4.4	4.4
90.0	3.0	3.0	3.0	3.0	3.0	3.5	3.5	3.5	3.6	4.4	4.8
100.0	3.3	3.3	3.3	3.3	3.5	3.8	3.8	3.8	3.8	4.8	5.2
110.0	3.5	3.5	3.5	3.5	3.5	3.8	3.8	3.8	3.8	5.2	5.6
120.0	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	5.6	5.6
130.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5.6	5.6
140.0	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	5.6	6.3
150.0	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	6.3	7.0
160.0	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	7.0	8.8
180.0	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	7.5	9.0
200.0	5.8	5.8	6.0	6.0	6.0	6.0	6.0	6.0	6.0	9.0	. . .
250.0	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	. . .	. . .
300.0	7.5	7.5	9.0	9.0	9.0	9.0	9.0	9.0	9.0	. . .	. . .

NOTES:
(1) Permissible variation under specified thickness, 0.3 mm.
(2) Thickness shall be measured 10 to 20 mm from the longitudinal edge.
(3) For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.
(4) For thickness measured at any location other than that specified in Note 2, the permissible maximum over tolerance shall be increased by 75%, rounded to the nearest 0.1 mm.

A2. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC. — SI UNITS

A2.1 Listed herein are permissible variations in dimensions, and notch toughness information, expressed in SI units.

TABLE A2.2
PERMISSIBLE VARIATIONS OVER IN WIDTH AND LENGTH FOR SHEARED PLATES (NOTE 1) AND LENGTH ONLY FOR UNIVERSAL MILL PLATES (NOTE 2)

Specified Dimensions, mm		Variations over Specified Width and Length for Thicknesses Given, mm							
		To 10, excl		10 to 16, excl		16 to 25, excl		25 to 50, incl[A]	
Length	Width	Width	Length	Width	Length	Width	Length	Width	Length
To 3 000 excl	To 1500 excl	10	13	11	16	13	19	16	25
	1500 to 2100 excl	11	16	13	17	16	22	19	25
	2100 to 2700 excl	13	19	16	22	19	25	25	29
	2700 and over	16	22	19	25	22	29	29	32
3 000 to 6 000 excl	To 1500 excl	10	19	13	22	16	25	19	29
	1500 to 2100 excl	13	19	16	22	19	25	22	32
	2100 to 2700 excl	14	22	17	24	21	29	25	35
	2700 and over	16	25	19	29	22	32	29	35
6 000 to 9 000 excl	To 1500 excl	10	25	13	29	16	32	19	38
	1500 to 2100 excl	13	25	16	29	19	32	22	38
	2100 to 2700 excl	14	25	17	32	22	35	25	38
	2700 and over	17	29	22	32	25	35	32	44
9 000 to 12 000 excl	To 1500 excl	11	29	13	32	16	35	19	41
	1500 to 2100 excl	13	32	16	35	19	38	22	41
	2100 to 2700 excl	14	32	19	35	22	38	25	48
	2700 and over	19	35	22	38	25	41	32	48
12 000 to 15 000 excl	To 1500 excl	11	32	13	38	16	41	19	48
	1500 to 2100 excl	13	35	16	38	19	41	22	48
	2100 to 2700 excl	16	35	19	38	22	41	25	48
	2700 and over	19	38	22	41	25	44	32	48
15 000 to 18 000 excl	To 1500 excl	13	44	16	48	19	48	22	57
	1500 to 2100 excl	16	44	19	48	22	48	25	57
	2100 to 2700 excl	16	44	19	48	22	48	29	57
	2700 and over	22	44	25	51	29	57	32	64
18 000 and over	To 1500 excl	14	51	19	54	22	57	25	70
	1500 to 2100 excl	19	51	22	54	25	57	29	70
	2100 to 2700 excl	19	51	22	54	25	57	32	70
	2700 and over	25	51	29	60	32	64	35	76

GENERAL NOTE: [A] Permissible variations in length apply also to carbon-steel and high-strength low-alloy steel Universal Mill plates up to 300 mm in width for thicknesses over 50 to 60 mm, incl.

NOTES:
(1) Carbon steel and high-strength low-alloy steel plates 40 mm and under in thickness. Alloy steel plates 30 mm and under in thickness.
(2) Carbon steel and high-strength low-alloy steel plates 65 mm and under in thickness. Alloy steel plates 50 mm and under in thickness.
(3) Permissible variation under in specified width and length: 6 mm.

TABLE A2.3
PERMISSIBLE VARIATIONS IN ROLLED WIDTH FOR UNIVERSAL MILL CARBON-STEEL, HIGH-STRENGTH LOW-ALLOY AND ALLOY-STEEL PLATES 400 MM AND UNDER IN THICKNESS

	Variations Over Specified Width for Thickness Given, mm					
Specified Width, mm	To 10, excl	10 to 16, excl	16 to 25, excl	25 to 50, excl	Over 50 to 250, incl	Over 250 to 400, incl
Over 200 to 500, excl	3	3	5	6	10	13
500 to 900, excl	5	6	8	10	11	14
900 and over	8	10	11	13	14	16

GENERAL NOTE: Permissible variation under specified width shall be 3 mm.

TABLE A2.4
PERMISSIBLE VARIATIONS IN DIAMETER FOR SHEARED CIRCULAR CARBON STEEL, HIGH-STRENGTH LOW-ALLOY STEEL AND ALLOY-STEEL PLATES 25 MM AND UNDER IN THICKNESS

	Permissible Variations Over Specified Diameter for Thicknesses Given, mm		
Specified Diameters, mm	To 10, excl	10 to 16, excl	16 to 25, incl
To 800, excl	6	10	13
800 to 2100, excl	8	11	14
2100 to 2700, excl	10	13	16
2700 to 3300, excl	11	14	17
3300 and over	13	16	19

GENERAL NOTE: No permissible variations under specified diameter.

TABLE A2.5
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR RECTANGULAR CARBON-STEEL AND HIGH-STRENGTH LOW-ALLOY STEEL PLATES WHEN GAS CUTTING IS SPECIFIED OR REQUIRED

Specified Thickness, mm	Variations Over for All Specified Widths or Lengths, mm
To 50, excl	13
50 to 100, excl	16
100 to 150, excl	19
150 to 200, excl	22
200 to 400, incl	25

NOTES:
(1) These variations may be taken all under or divided over and under, if so specified.
(2) Plates with universal rolled edges will be gas cut to length only.

98

TABLE A2.6
PERMISSIBLE VARIATIONS IN DIAMETER FOR GAS-CUT CIRCULAR CARBON-STEEL AND HIGH-STRENGTH LOW-ALLOY STEEL PLATES

Specified Diameters, mm	Variations Over Specified Diameter for Thicknesses Given, mm					
	To 25, excl	25 to 50, excl	50 to 100, excl	100 to 150, excl	150 to 200, excl	200 to 400, excl
To 800, excl	10	10	13	13	16	19
800 to 2100, excl	10	13	13	16	19	22
2100 to 2700, excl	13	14	16	19	22	25
2700 to 3300, excl	13	14	17	22	25	29
3300 and over	16	19	22	25	29	32

GENERAL NOTE: No permissible variations under specified diameter.

TABLE A2.7
PERMISSIBLE CAMBER FOR CARBON STEEL SHEARED OR GAS-CUT RECTANGULAR PLATES ALL THICKNESSES

Maximum permissible camber, mm = length in millimetres/500

GENERAL NOTE: Camber, as it relates to plates, is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

TABLE A2.8
PERMISSIBLE CAMBER FOR CARBON STEEL, HIGH-STRENGTH LOW-ALLOY STEEL AND ALLOY STEEL UNIVERSAL MILL PLATES AND HIGH-STRENGTH LOW-ALLOY STEEL AND ALLOY STEEL SHEARED OR GAS-CUT RECTANGULAR PLATES

Width, mm	Camber for Width Given, mm
To 750, incl	Length/300
Over 750 to 1500	Length/250

GENERAL NOTE: Camber, as it relates to plates, is the horizontal edge curvature in the length, measured over the entire length of the plate in the flat position.

98

TABLE A2.9
PERMISSIBLE VARIATIONS FROM FLATNESS FOR CARBON-STEEL PLATES

Specified Thickness, mm	Permissible Variations from a Flat Surface for Specified Widths, mm										
	To 900, excl	900 to 1200	1200 to 1500	1500 to 1800	1800 to 2100	2100 to 2400	2400 to 2700	2700 to 3000	3000 to 3600	3600 to 4200	4200 and Over
To 6, excl	14	19	24	32	35	38	41	44	48	...	...
6 to 10, excl	13	16	19	24	29	32	35	38	41	...	...
10 to 12, excl	13	14	16	16	19	22	25	29	32	48	54
12 to 20, excl	11	13	14	16	16	19	25	25	29	38	51
20 to 25, excl	11	13	14	16	16	16	19	22	25	35	44
25 to 50, excl	10	13	13	14	14	16	16	16	18	29	38
50 to 100, excl	8	10	11	13	13	13	13	14	16	22	29
100 to 150, excl	10	11	13	13	14	14	16	19	22	22	25
150 to 200, excl	11	13	13	16	18	19	22	22	25	25	25
200 to 250, excl	13	13	16	18	19	21	22	24	25	25	25
250 to 300, excl	13	16	19	21	22	24	25	25	25	25	25
300 to 400, incl	16	19	21	22	24	25	25	25	25	25	...

NOTES:
(1) *Flatness Variations for Length* — The longer dimension specified is considered the length, and variation in flatness along the length shall not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm of longer plates.
(2) *Flatness Variations for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.
(3) When the longer dimension is under 900 mm, the variation in flatness along the length and across the width shall not exceed 6 mm in each direction. When the longer dimension is from 900 to 1800 mm, inclusive, the flatness variation shall not exceed 75% of the tabular amount for the specified width, but in no case less than 6 mm.
(4) The tolerances given in this table apply to plates that have a minimum specified tensile strength not over 400 MPa or compatible chemistry or hardness. For plates specified to a higher minimum tensile strength or compatible chemistry or hardness, the limits given in the table are increased to $1\frac{1}{2}$ times the amounts in the above table.
(5) This table and notes cover the flatness tolerances of circular and sketch plates, based on the maximum dimensions of those plates.

TABLE A2.10
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR RECTANGULAR ALLOY-STEEL PLATES WHEN GAS CUTTING IS SPECIFIED OR REQUIRED

Specified Thickness, mm	Variations Over for All Specified Widths and Lengths, mm
To 50, excl	19
50 to 100, excl	25
100 to 150, excl	29
150 to 200, excl	33
200 to 400, incl	38

NOTES:
(1) These variations may be taken all under or divided over and under, if so specified.
(2) Plates with universal rolled edges will be gas cut to length only.

TABLE A2.11
PERMISSIBLE VARIATIONS IN DIAMETER FOR GAS CUT CIRCULAR ALLOY-STEEL PLATES

Specified Diameter, mm	Variations Over Specified Diameter for Thicknesses Given, mm					
	To 25, excl	25 to 50, excl	50 to 100, excl	100 to 150, excl	150 to 200, excl	200 to 400, incl
To 800, excl	13	13	19	19	25	25
800 to 2100, excl	13	16	22	25	29	32
2100 to 2700, excl	16	19	25	29	32	35
2700 to 3300, incl	22	25	29	32	35	38

GENERAL NOTE: No permissible variations under specified diameter.

TABLE A2.12
PERMISSIBLE VARIATIONS FROM FLATNESS FOR HIGH-STRENGTH LOW-ALLOY AND ALLOY-STEEL PLATES

98

Specified Thickness, mm	Flatness Tolerances for Specified Widths, mm										
	To 900, excl	900 to 1200	1200 to 1500	1500 to 1800	1800 to 2100	2100 to 2400	2400 to 2700	2700 to 3000	3000 to 3600	3600 to 4200	4200 and over
To 6, excl	21	29	35	48	51	57	60	67	70	. . .	. . .
6 to 10, excl	19	24	29	35	44	48	51	57	60	. . .	. . .
10 to 12, excl	19	22	24	24	29	33	38	41	48	70	79
12 to 20, excl	16	19	21	22	25	29	32	35	41	57	76
20 to 25, excl	16	19	22	22	24	25	29	33	38	51	67
25 to 50, excl	14	16	19	21	22	24	25	25	25	41	57
50 to 100, excl	13	14	18	19	19	19	19	22	25	32	41
100 to 150, excl	14	18	19	19	22	22	24	29	32	32	38
150 to 200, excl	16	19	19	24	25	29	32	33	38	38	38
200 to 250, excl	19	21	24	25	29	32	33	35	38	38	38
250 to 300, excl	19	24	29	32	33	35	38	38	38	38	38
300 to 400, incl	22	25	30	33	35	38	38	38	38	38	38

NOTES:
(1) *Flatness Tolerances for Length* — The longer dimension specified is considered the length and variations from a flat surface along the length shall not exceed the tabular amount for the specified width in plates up to 4000 mm in length, or in any 4000 mm of longer plates.
(2) *Flatness Tolerances for Width* — The flatness variation across the width shall not exceed the tabular amount for the specified width.
(3) When the longer dimension is under 900 mm, the variation shall not exceed 10 mm. When the larger dimension is from 900 to 1800 mm, incl, the variation shall not exceed 75% of the tabular amount for the specified width.
(4) This table and notes cover the tolerances for flatness of circular and sketch plates, based on the maximum dimensions of those plates.

TABLE A2.13
WAVINESS TOLERANCES FOR RECTANGULAR PLATES, UNIVERSAL MILL PLATES AND CIRCULAR AND SKETCH PLATES

Flatness Tolerance from Tables A2.9 and A2.12	When Number of Waves in 4000 mm is:						
	1	2	3	4	5	6	7
8	8	6	5	3	3	2	2
10	10	8	5	5	3	2	2
11	11	8	6	5	3	3	2
13	13	10	8	5	5	3	2
14	14	11	8	6	5	3	2
16	16	13	10	6	5	3	2
17	17	13	10	8	5	5	2
19	19	14	11	8	6	5	2
21	21	16	11	8	6	5	2
22	22	17	13	10	6	5	2
24	24	17	13	10	8	6	5
25	25	19	14	11	8	6	5
29	29	22	16	13	10	6	5
32	32	24	17	13	10	8	6
35	35	27	19	14	11	8	6
38	38	29	22	16	13	10	6
41	41	32	24	17	13	10	8
44	44	33	25	19	14	11	8
48	48	37	27	21	14	11	8
51	51	38	29	22	16	13	10
54	54	41	30	22	17	13	10
57	57	43	32	24	17	14	10
60	60	46	33	25	19	14	11
64	64	48	37	27	21	14	11
67	67	51	38	29	21	16	11
70	70	52	40	29	22	16	13
73	73	56	41	30	24	17	13
76	76	57	43	32	24	17	14
79	79	60	44	33	25	19	14

GENERAL NOTE: Waviness denotes the deviation of the top or bottom surface from a horizontal line, when the plate is resting on a flat surface, as measured in an increment of less than 4000 mm of length. The waviness tolerance is a function of the flatness tolerance as obtained from Tables A2.9 and A2.12.

TABLE A2.14
VISIBLE EDGE INDICATIONS EXTENDING APPROXIMATELY PARALLEL TO ROLLED SURFACES

Plate Specification and Thickness	Acceptable		Remove by Grinding		Acceptable on Edges Cut in Fabrication	
	Depth	Length[B]	Depth	Length[B]	Depth	Length[B]
Column	1	2	3	4	5	6
Nonkilled,[A] to 50 mm, incl	3 mm, max	any	over 3 to 6 mm, incl	over 25 mm	6 mm max	any
Killed,[C] to 150 mm, incl	2 mm, max	any	over 2 to 3 mm, incl	over 25 mm	3 mm max	any
Killed,[C] over 150 mm	3 mm, max	any	over 3 to 13 mm, incl	over 25 mm	13 mm max	any

NOTES:
[A] Specifications: A 285; A 433; A 442 in thicknesses to 25 mm, incl; or A 455.
[B] Laminar-type discontinuities 25 mm and less in length are acceptable and do not require exploration.
[C] The specifications in 1.1 Scope, of this document other than those listed in the above footnote *A*.

TABLE A2.15
GENERALLY AVAILABLE GRADE-THICKNESS-MINIMUM TEST TEMPERATURE COMBINATIONS MEETING CHARPY V-NOTCH REQUIREMENTS INDICATED (NORMALIZED OR QUENCHED AND TEMPERED CONDITION)

Acceptance Criteria Charpy V-Notch Energy Absorption				Test Temperature, °C for Plate Thicknesses (Unless Otherwise Agreed Upon)			
Class[A]	Average For 3 Specimens[B], J, min	Minimum For 1 Specimen[B], J	Specification and Grade	25 mm and Under	Over 25 mm to 50 mm, incl.	Over 50 mm to 75 mm, incl.	Over 75 mm to 125 mm, incl.
I	14	10	A 285 Grade A	+4	+16	...	...
			A 285 Grade B	+10	+21	...	...
			A 285 Grade C	+16	+27	...	...
			A 442 Grade 55	−1	...	...	...
			A 442 Grade 60	+2	...	...	...
II	18	14	A 455	−4	...	...	...
III	18	14	A 203 Grade A	−68	−68	−60	...
			A 203 Grade D	−101	−101	−87	...
			A 442 Grade 55 (38 mm max thickness)	...	−29	...	...
			A 442 Grade 60 (38 mm max thickness)	...	−26	...	...
			A 516 Grade 55	−51	−51	−46	−46
			A 516 Grade 60	−51	−46	−46	−46
			A 516 Grade 65	−51	−46	−40	−32
			A 537 Class 1 (Over 64–100 mm)	...	...	−60	−46
			A 662 Grade A	−60	−60	...	...
			A 662 Grade B	−51	−51	...	...
IV	20	16	A 203 Grade B	−68	−68	−60	...
			A 203 Grade E	−101	−101	−87	...
			A 203 Grade F (100 mm max)	...	...	−107	−107
			A 299	−7	−1	−1	+4
			A 516 Grade 70	−46	−40	−35	−29
			A 537 Class 1 (64 mm max)	−62	−60	−60	...
			A 537 Class 2 (Over 64–100 mm)	...	...	−60	−46
			A 662 Grade C	−46	−46	...	...

(Continued)

TABLE A2.15 (CONT'D)
GENERALLY AVAILABLE GRADE-THICKNESS-MINIMUM TEST TEMPERATURE COMBINATIONS MEETING CHARPY V-NOTCH REQUIREMENTS INDICATED (NORMALIZED OR QUENCHED AND TEMPERED CONDITION)

Acceptance Criteria Charpy V-Notch Energy Absorption				Test Temperature, °C for Plate Thicknesses (Unless Otherwise Agreed Upon)			
Class[A]	Average For 3 Specimens[B], J, min	Minimum For 1 Specimen[B], J	Specification and Grade	25 mm and Under	Over 25 mm to 50 mm, incl.	Over 50 mm to 75 mm, incl.	Over 75 mm to 125 mm, incl.
V	27	20	A 203 Grade F	−107	−107	...	...
			A 537 Class 2 (64 mm max)	−68	−68	−68	...
			A 612	−46	...	...	...
			A 724 Grade A	−46	...	...	...
Lateral Expansion mm, Minimum Each Specimen Transverse Test							
VI	0.38	...	A 353	−196	−196	...	...
			A 553 Type I	−196	−196	...	...
			A 553 Type II	−170	−170	...	...
			A 645	−170	−170	...	...
			A 517 all (64 mm max thickness)	[C]	[C]	...	...
			A 724 Grade B	−46	...	...	...

GENERAL NOTE: The minimum temperatures listed are for longitudinal tests. For transverse tests, the available minimum temperature may be somewhat higher.

NOTES:
[A] Class I is *Other Than Fully Killed* with a specified minimum tensile strength of 450 MPa or lower.
Class II is *Other Than Fully Killed* with a specified minimum tensile strength of over 450 to 520 MPa, incl.
Class III is *Fully Killed* with a specified minimum tensile strength of 450 MPa or lower.
Class IV is *Fully Killed* with a specified minimum tensile strength of over 450 to 520 MPa, incl.
Class V is *Fully Killed* with a specified minimum tensile strength of over 520 MPa to but not including 655 MPa.
Class VI is *Fully Killed* with a specified minimum tensile strength of 655 MPa and over.
[B] Full size (10 by 10 mm) specimens.
[C] Testing temperatures as specified on order but no higher than 0°C.

TABLE A2.16
PERMISSIBLE VARIATIONS IN WIDTH FOR MILL EDGE CARBON STEEL AND HIGH-STRENGTH LOW-ALLOY STEEL PLATES PRODUCED ON STRIP MILLS

98

Note — Applies to either plates produced from coils or plates produced in discrete cut lengths of flat product.

Specified Width, mm	Variations Over Specified Width, mm[A]
To 360, excl	11
360 to 430, excl	13
430 to 480, excl	14
480 to 530, excl	16
530 to 610, excl	17
610 to 660, excl	21
660 to 710, excl	24
710 to 890, excl	29
890 to 1270, excl	32
1270 to 1520, excl	38
1520 to 1650, excl	41
1650 to 1780, excl	44
1780 to 2030, excl	47
2030 and over	51

NOTE:
[A] No permissible variation under specified width.

APPENDIX

(Nonmandatory Information)

X1. COILED PRODUCTS

X1.1 Continuous wide hot strip rolling mills are normally equipped with coilers. Regardless of the different types of systems employed during or following the rolling operations, it is common for the steel to be reeled into the coiler at temperatures in the stress-relieving range. In general, these temperatures are higher as material thickness increases. The coils subsequently cool to ambient temperature with outer and inner laps cooling more rapidly than central laps. The difference in cooling rate can result in measurable differences in the mechanical properties throughout a coil. Data confirm reduced yield and tensile strength, and increased percent elongation, for the product with slower cooling rates from the coiling temperature to ambient. These differences are in addition to the effects on mechanical properties caused by differences in heat analysis and chemical segregation.

X2. VARIATION OF TENSILE PROPERTIES IN PLATES

X2.1 The tension requirements of this specification are intended only to characterize the tensile properties of a plate-as-rolled for determination of conformance to the requirements of the material specifications. These testing procedures are not intended to define the upper or lower limits of tensile properties at all possible test locations within a plate-as-rolled. It is well known and documented that tensile properties vary within a plate-as-rolled or individual piece of steel as a function of chemical composition, processing, testing procedure and other factors. It is, therefore, incumbent on designers and engineers to use sound engineering judgment when using tension test results shown on mill test reports. The testing procedures of this specification have been found to provide material adequate for normal pressure vessel design criteria.

X2.2 A survey of the variation to be expected in tensile properties obtained from plates and structural shapes was determined, based on review of the AISI data (SU20), that the variation in tensile properties within a plate-as-rolled can be expressed as a function of specified requirements; one conducted by the American Iron and Steel Institute (AISI). The results of this survey are contained in a *Contributions to the Metallurgy of Steel* entitled "The Variation of Product Analysis and Tensile Properties — Carbon Steel Plates, and Wide Flange Shapes" (SU/18, SU/19, and SU/20), published in September 1974. The data are presented in tables of probability that tensile properties at other than the official location may differ from those of the reported test location.

X2.3 This specification contains no requirements applicable to product tension tests; conformance to the material specifications is determined on the basis of tests performed at the place of manufacture prior to shipment, unless otherwise specified.

X2.4 A Task Group of ASTM Subcommittee A01.11 has standard deviation equals approximately 3% of required tensile strength, 5% of required yield strength, and 3 percentage units of required elongation.

X3. VARIATION IN CHARPY V-NOTCH TESTS

X3.1 A survey of the variation to be expected in Charpy V-Notch test results obtained from three common fine grain plate steels was conducted by the American Iron and Steel Institute (AISI). The results of the survey are contained in a Contributions to the Metallurgy of Steel entitled, "The Variations of Charpy V-Notch Impact Test Properties in Steel Plates," (SU/24), published January 1979. The survey data consists of test values obtained from six locations in addition to the locations specified in 12.1.3 of this specification. The plate conditions tested involved as-rolled, normalized, and quench and tempered. Sufficient full-size specimens were taken from each sample so that three longitudinal and three transverse specimens could be broken at three test temperatures defined for each grade. The data is presented in tables of probability that impact properties at other than the official location which may differ from those of the reported test location. Additional data of the same type, but utilizing samples from thicker plates, was published by AISI as SU/27.

SPECIFICATION FOR STEEL BARS, CARBON AND ALLOY, HOT-WROUGHT AND COLD-FINISHED, GENERAL REQUIREMENTS FOR

SA-29/SA-29M

(Identical with ASTM Specification A 29/A 29M-93a)

1. Scope

1.1 This specification covers a group of common requirements which, unless otherwise specified in the purchase order or in an individual specification, shall apply to carbon and alloy steel bars under each of the following ASTM specifications (or under any other ASTM specification which invokes this specification or portions thereof):

Title of Specification	ASTM Designation
Hot-Rolled Carbon Steel Bars:	
Steel Bars, Carbon, Quenched and Tempered	A 321
Steel Bars and Shapes, Carbon Rolled from "T" Rails	A 499
Steel Bars, Carbon, Merchant Quality, M-Grades	A 575
Steel Bars, Carbon, Hot-Wrought, Special Quality	A 576
Steel Bars, Carbon, Merchant Quality, Mechanical Properties	A 663
Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties	A 675
Steel Bars for Springs, Carbon and Alloy	A 689
Steel Bars, Carbon, Hot-Wrought, Special Quality, for Fluid Power Applications	A 695
Cold-Finished Carbon Steel Bars:	
Steel Bars, Carbon, Cold-Finished, Standard Quality	A 108
Stress-Relieved Steel Bars Subject to Mechanical Property Requirements, Cold-Drawn Carbon	A 311/A 311M
Hot-Rolled Alloy Steel Bars:	
Steel Bars, Alloy, Standard Grades	A 322
Steel Bars, Alloy, Subject to End-Quench Hardenability Requirements	A 304
Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered	A 434
Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both	A 739
Cold-Finished Alloy Steel Bars:	
Steel Bars, Alloy, Cold-Finished	A 331
Steel Bars, Alloy, Hot-Rolled or Cold-Finished, Quenched and Tempered	A 434
Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components	A 696

1.2 In case of any conflict in requirements, the requirements of the purchase order, the individual material specification, and this general specification shall prevail in the sequence named.

1.3 The values stated in inch-pound units or SI units are to be regarded as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 For purposes of determining conformance to this specification and the various material specifications referenced in 1.1, dimensional values shall be rounded to the nearest unit in the right-hand place of figures

used in expressing the limiting values in accordance with the rounding method of Practice E 29.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 112 Test Methods for Determining the Average Grain Size

2.2 *Federal Standards:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.3 *Military Standard:*

MIL-STD-163 Steel Mill Products — Preparation for Shipment and Storage

2.4 *Other Standards:*

AIAG B-1 Bar Code Symbology Standard for 3-of-9 Bar Codes

AIAG B-5 02.00 Primary Metals Tag Application Standard

3. Terminology

3.1 *Descriptions of Terms Specific To This Standard:*

3.1.1 *Hot-Wrought Steel Bars* — Steel bars produced by hot forming ingots, blooms, billets, or other semifinished forms to yield straight lengths (or coils, depending upon size, section, and mill equipment) in sections which are uniform throughout their length, and in the following sections and sizes:

3.1.1.1 *Rounds,* $\frac{7}{32}$ to 10.0 in. [5.5 to 250 mm], inclusive,

3.1.1.2 *Squares,* $\frac{7}{32}$ to 6.0 in. [6 to 160 mm], inclusive

3.1.1.3 *Round-Cornered Squares,* $\frac{7}{32}$ to 8.0 in. [6 to 200 mm], inclusive,

3.1.1.4 *Flats,* $\frac{1}{4}$ to 8 in. inclusive, in width: $\frac{12}{64}$ in. in minimum thickness up to 6 in. in width; and 0.230 in. in minimum thickness for over 6 to 8 in. in width, inclusive [over 5 mm in thickness up to 150 mm in width; and over 6 mm in thickness for over 150 mm through 200 mm in width]. Maximum thickness for all widths is 4 in. [100 mm].

3.1.1.5 *Hexagons and Octagons,* $\frac{1}{4}$ to $4\frac{1}{16}$ in. [6 to 103 mm], inclusive, between parallel surfaces,

3.1.1.6 *Bar Size Shapes* — Angles, channels, tees, zees, when their greatest cross-sectional dimension is under 3 in. [75 mm], and

3.1.1.7 *Special Bar Sections* — Half-rounds, ovals, half-ovals, other special bar size sections.

3.1.2 *Cold-Finished Steel Bars* — Steel bars produced by cold finishing previously hot-wrought bars by means of cold drawing, cold forming, turning, grinding, or polishing (singly or in combination) to yield straight lengths or coils in sections which are uniform throughout their length and in the following sections and sizes:

3.1.2.1 *Rounds,* 9 in. [230 mm] and under in diameter,

3.1.2.2 *Squares,* 6 in. [150 mm] and under between parallel surfaces,

3.1.2.3 *Hexagons,* 4 in. [100 mm] and under between parallel surfaces,

3.1.2.4 *Flats,* $\frac{1}{8}$ in. [3 mm] and over in thickness and not over 12 in. [300 mm] in width, and

3.1.2.5 *Special Bar Sections.*

3.1.3 *Lot* — Unless otherwise specified in the contract or order, a lot shall consist of all bars submitted for inspection at the same time of the same heat, condition, finish, size, or shape. For bars specified in the quenched and tempered condition, when heat treated in batch-type furnaces, a lot shall consist of all bars from the same heat, of the same prior condition, the same size, and subjected to the same heat treatment in one tempering charge. For bars specified in the quenched and tempered condition, when heat treated without interruption in a continuous-type furnace, a lot shall consist of all bars from the same heat, of the same prior condition, of the same size, and subjected to the same heat treatment.

4. Chemical Composition

4.1 *Limits:*

4.1.1 The chemical composition shall conform to the requirements specified in the purchase order or the individual product specifications. For convenience the grades commonly specified for carbon steel bars are shown in Table 1 and for alloy steel bars in Table 2. Bars may be ordered to these grade designations and when so ordered shall conform to the specified limits by heat analysis.

4.1.2 When compositions other than those shown in Tables 1 and 2 are required, the composition limits shall be prepared using the ranges and limits shown in Table 3 for carbon steel and Table 4 for alloy steel.

4.2 *Heat or Cast Analysis:*

4.2.1 The chemical composition of each heat or cast shall be determined by the manufacturer in accordance with Test Methods, Practices, and Terminology A 751.

4.2.2 The heat or cast analysis shall conform to the requirements specified in the product specification or purchase order. These can be the heat chemical range and limit for a grade designated in Tables 1 or 2, or another range and limit in accordance with 4.1.2, or with requirements of the product specification.

NOTE 1 — Heat analysis for lead is not determinable since lead is added to the ladle stream while each ingot is poured. When specified as an added element to a standard steel, the percentage of lead is reported as 0.15 to 0.33 incl, which is the range commonly specified for this element.

4.2.3 If requested or required, the heat analysis shall be reported to the purchaser or his representative.

4.2.4 Reporting of significant figures and rounding shall be in accordance with Test Methods, Practices, and Terminology A 751.

4.3 *Product Analysis:*

4.3.1 Merchant quality carbon bar steel is not subject to rejection for product analysis unless misapplication of a heat is clearly indicated.

4.3.2 Analyses may be made by the purchaser from finished bars other than merchant quality representing each heat of open-hearth, basic-oxygen, or electric-furnace steel. The chemical composition thus determined shall not vary from the limits specified in the applicable specification by more than the amounts prescribed in Tables 5 and 6, but the several determinations of any element, excluding lead, in a heat may not vary both above and below the specified range. Rimmed or capped steel is characterized by a lack of homogeneity in its composition, especially for the elements carbon, phosphorus, and sulfur; therefore, when rimmed or capped steel is specified or required, the limitations for these elements shall not be applicable. Because of the degree to which phosphorus and sulfur segregate, the limitations for these elements shall not be applicable to rephosphorized or resulfurized steels.

4.3.3 Samples for product analysis shall be taken by one of the following methods:

4.3.3.1 Applicable to small sections whose cross-sectional area does not exceed 0.75 in.^{2} [500 mm^2] such as rounds, squares, hexagons, etc. Chips are taken by milling or machining the full cross section of the piece. Drilling is not a feasible method for sampling sizes 0.75 in.^{2} and smaller.

4.3.3.2 Applicable to products where the width of the cross section greatly exceeds the thickness, such as bar size shapes and light flat bars. Chips are taken by drilling entirely through the steel at a point midway between the edge and the middle of the section, or by milling or machining the entire cross section.

4.3.3.3 Applicable to large rounds, squares semi-finished, etc. Chips are taken at any point midway between the outside and the center of the piece by drilling parallel to the axis or by milling or machining the full cross section in cases where these methods are not practicable, the piece may be drilled on the side, but chips are not taken until they represent the portion midway between the outside and the center.

4.3.3.4 When the steel is subject to tension test requirements, the tension test specimen can also be used for product analysis. In that case, chips for product analysis can be taken by drilling entirely through the tension test specimens or by the methods described in 4.3.3.1.

4.3.4 When chips are taken by drilling, the diameter of the drill used shall conform to the following:

Area of Sample Cross Section, in.^{2} (cm^2)	Approximate Drill Diameter, in. (mm)
16 [100] or less	½ [12.5]
Over 16 [100]	1 [25.0]

4.3.5 The minimum number of samples to be taken from material representing the same heat or lot before rejection by the purchaser shall be as follows:

	Minimum Number of Samples
15 tons [15 Mg] and under	4
Over 15 tons [15 Mg]	6

4.3.6 In case the number of pieces in a heat is less than the number of samples required, one sample from each piece shall be considered sufficient.

4.3.7 In the event that product analysis determinations are outside the permissible limits as prescribed in 4.3.2, additional samples shall be analyzed and the acceptability of the heat negotiated between the purchaser and the producer.

4.4 *Referee Analysis* — In case a referee analysis is required and agreed upon to resolve a dispute concerning the results of a chemical analysis, the referee analysis shall be performed in accordance with the latest issue of Test Methods, Practices, and Terminology A 751, unless otherwise agreed upon between the manufacturer and the purchaser.

5. Grain Size Requirement

5.1 *Austenitic Grain Size*

5.1.1 When a coarse austenitic grain size is specified, the steel shall have a grain size number of 1 to 5 exclusive as determined in accordance with Test Methods E 112. Conformance to this grain size of 70% of the grains in the area examined shall constitute the basis of acceptance. One test per heat shall be made.

5.1.2 When a fine austenitic grain size is specified, the steel shall have a grain size number of 5 or higher as determined in accordance with Test Methods E 112. Conformance to this grain size of 70% of the area examined shall constitute the basis of acceptance. One test per heat shall be made unless the provision of 5.1.2.1 is exercised.

5.1.2.1 When aluminum is used as the grain refining element, the fine austenitic grain size requirement shall be deemed to be fulfilled if, on heat analysis, the aluminum content is not less than 0.020% total aluminum or, alternately, 0.015% acid soluble aluminum. The aluminum content shall be reported. The grain size test specified in 5.1.2 shall be the referee test.

5.1.2.2 If specified on the order, one grain size test per heat shall be made and the austenitic grain size of the steel, as represented by the test, shall be number 5 or higher.

5.1.2.3 By agreement between purchaser and supplier, columbium or vanadium or both may be used for grain refining instead of or with aluminum. The maximum contents shall be:

Cb	0.05 max.
V	0.08 max.
Cb + V	0.06 max.

The content of the elements shall be reported with the heat analysis.

5.1.2.4 The austenitic grain size test shall be required.

6. Mechanical Property Requirements

6.1 *Test Specimens:*

6.1.1 *Selection* — Test specimens shall be selected in accordance with the requirements of the applicable product specification or in accordance with Supplement I of the latest issue of Test Methods and Definitions A 370, in the sequence named.

6.1.2 *Preparation* — Unless otherwise specified in the applicable product specification, test specimens shall be prepared in accordance with the latest issue of Test Methods and Definitions A 370, and especially Supplement I thereof.

6.2 *Methods of Mechanical Testing* — All mechanical tests shall be conducted in accordance with the latest issue of Test Methods and Definitions A 370, and especially Supplement I thereof, on steel bar products.

6.3 *Retests:*

6.3.1 If any test specimen shows defective machining or develops flaws, the specimen may be discarded and another substituted.

6.3.2 If the percentage elongation of any tension specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. [20 mm] from the center of a 2 in. [50 mm] specimen, or is outside the middle half of the gage length of an 8 in. [200 mm] specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

6.3.3 For “as-wrought” material, if the results for any original tension specimen are within 200 psi [14 MPa] of the required tensile strength, within 1000 psi [7 MPa] of the required yield point, or within 2% of the required elongation, retesting shall be permitted. If the original testing required only one test, the retest shall consist of two random tests from the heat or lot

involved. If the original testing required two tests of which one failed by the amounts listed in this paragraph, the retest shall be made on one random test from the heat or lot. If the results on the retest specimen or specimens meet the specified requirements, the heat or test lot will be accepted. If the results of one retest specimen do not meet the specified requirements, the material is subject to rejection.

6.3.4 For thermally treated bars, if the results of the mechanical tests do not conform to the requirements specified, two more tests may be selected for each bar failing, and each of these retests shall conform to the requirements of the product specification.

6.3.5 If a bend specimen fails, due to conditions of bending more severe than required by the specification, a retest shall be permitted from the heat or test lot involved for which one random specimen for each original specimen showing failure shall be used. If the results on the retest specimen meet the requirements of the specification, the heat or test lot will be accepted.

7. Dimensions, Mass, and Permissible Variations

7.1 *Hot-Wrought Bars* — The permissible variations for dimensions of hot-wrought carbon and alloy steel bars shall not exceed the applicable limits stated in Tables A1.1 to A1.10 for inch-pound values and Tables A2.1 to A2.10 and S1.1 for metric values.

7.2 *Cold-Finished Bars* — The permissible variations for dimensions of cold-finished carbon and alloy steel bars shall not exceed the applicable limits stated in Tables A1.11 to A1.14 for inch-pound values and Tables A2.11 to A2.14 for metric values.

8. Workmanship, Finish, and Appearance

8.1 The material shall be free of injurious defects and shall have a workmanlike finish.

9. Rework and Retreatment

9.1 For thermally treated bars only, the manufacturer may retreat a lot one or more times, and retests shall be made in the same manner as the original tests. Each such retest shall conform to the requirements specified.

10. Inspection

10.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

10.2 All required tests and inspection shall be made by the manufacturer prior to shipment.

11. Rejection

11.1 Unless otherwise specified, any rejection because of noncompliance to the requirements of the specification shall be reported by the purchaser to the manufacturer within 30 working days after receipt of samples.

11.2 Material that shows imperfections capable of adversely affecting processability subsequent to its acceptance at the purchaser's works will be rejected, and the manufacturer shall be notified.

12. Rehearing

12.1 Samples that represent rejected material shall be preserved for two weeks from the date rejection is reported to the manufacturer. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

13. Product Marking

13.1 *Civilian Procurement* — Bars of all sizes, when loaded for shipment, shall be properly identified with the name or brand of manufacturer, purchaser's name and order number, the ASTM designation (year date is not required), grade number where appropriate, size and length, weight of lift, and the heat number for identification. Unless otherwise specified, the method of marking is at the manufacturer's option and may be made by hot stamping, cold stamping, painting, or marking tags attached to the lifts of bars.

13.1.1 Bar code marking may be used as an auxiliary method of identification. Such bar-code mark-

ings shall be of the 3-of-9 type and shall conform to AIAG B1. When bar-coded tags are used, they shall conform to AIAG B5.

13.2 *Government Procurement:*

13.2.1 Marking for shipment shall be in accordance with the requirements specified in the contract or order and shall be in accordance with MIL-STD-163 for military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

13.2.2 For government procurement by the Defense Supply Agency, the bars shall be continuously marked for identification in accordance with Fed. Std. No. 183.

14. Packaging

14.1 *Civilian Procurement* — Unless otherwise specified, the bars shall be packaged and loaded in accordance with Practices A 700.

14.2 *Government Procurement* — MIL-STD-163 shall apply when packaging is specified in the contract or order, or when Level A for preservation, packaging, and packing is specified for direct procurement by or direct shipment to the government.

15. Keywords

15.1 alloy steel bars; carbon steel bars; cold finished steel bars; general delivery requirement; hot wrought steel bars; steel bars

TABLE 1
GRADE DESIGNATIONS AND CHEMICAL COMPOSITIONS OF CARBON STEEL BARS

Grade Designation	Heat Chemical Ranges and Limits, %			
	Carbon	Manganese	Phosphorus, max	Sulfur, max[A]
Nonresulfurized Carbon Steels[B,C,D,G,H]				
1005	0.06 max	0.35 max	0.040	0.050
1006	0.08 max	0.25–0.40	0.040	0.050
1008	0.10 max	0.30–0.50	0.040	0.050
1010	0.08–0.13	0.30–0.60	0.040	0.050
1011	0.08–0.13	0.60–0.90	0.040	0.050
1012	0.10–0.15	0.30–0.60	0.040	0.050
1013	0.11–0.16	0.50–0.80	0.040	0.050
1015	0.13–0.18	0.30–0.60	0.040	0.050
1016	0.13–0.18	0.60–0.90	0.040	0.050
1017	0.15–0.20	0.30–0.60	0.040	0.050
1018	0.15–0.20	0.60–0.90	0.040	0.050
1019	0.15–0.20	0.70–1.00	0.040	0.050
1020	0.18–0.23	0.30–0.60	0.040	0.050
1021	0.18–0.23	0.60–0.90	0.040	0.050
1022	0.18–0.23	0.70–1.00	0.040	0.050
1023	0.20–0.25	0.30–0.60	0.040	0.050
1025	0.22–0.28	0.30–0.60	0.040	0.050
1026	0.22–0.28	0.60–0.90	0.040	0.050
1029	0.25–0.31	0.60–0.90	0.040	0.050
1030	0.28–0.34	0.60–0.90	0.040	0.050
1034	0.32–0.38	0.50–0.80	0.040	0.050
1035	0.32–0.38	0.60–0.90	0.040	0.050
1037	0.32–0.38	0.70–1.00	0.040	0.050
1038	0.35–0.42	0.60–0.90	0.040	0.050
1039	0.37–0.44	0.70–1.00	0.040	0.050
1040	0.37–0.44	0.60–0.90	0.040	0.050
1042	0.40–0.47	0.60–0.90	0.040	0.050
1043	0.40–0.47	0.70–1.00	0.040	0.050
1044	0.43–0.50	0.30–0.60	0.040	0.050
1045	0.43–0.50	0.60–0.90	0.040	0.050
1046	0.43–0.50	0.70–1.00	0.040	0.050
1049	0.46–0.53	0.60–0.90	0.040	0.050
1050	0.48–0.55	0.60–0.90	0.040	0.050
1053	0.48–0.55	0.70–1.00	0.040	0.050
1055	0.50–0.60	0.60–0.90	0.040	0.050
1059	0.55–0.65	0.50–0.80	0.040	0.050
1060	0.55–0.65	0.60–0.90	0.040	0.050
1064	0.60–0.70	0.50–0.80	0.040	0.050
1065	0.60–0.70	0.60–0.90	0.040	0.050
1069	0.65–0.75	0.40–0.70	0.040	0.050
1070	0.65–0.75	0.60–0.90	0.040	0.050
1071	0.65–0.70	0.75–1.05	0.040	0.050
1074	0.70–0.80	0.50–0.80	0.040	0.050
1075	0.70–0.80	0.40–0.70	0.040	0.050
1078	0.72–0.85	0.30–0.60	0.040	0.050
1080	0.75–0.88	0.60–0.90	0.040	0.050
1084	0.80–0.93	0.60–0.90	0.040	0.050
1086	0.80–0.93	0.30–0.50	0.040	0.050
1090	0.85–0.98	0.60–0.90	0.040	0.050
1095	0.90–1.03	0.30–0.50	0.040	0.050
Resulfurized Carbon Steels[B,D,H]				
1108	0.08–0.13	0.60–0.80	0.040	0.08–0.13
1109	0.08–0.13	0.60–0.90	0.040	0.08–0.13
1110	0.08–0.13	0.30–0.60	0.040	0.08–0.13
1116	0.14–0.20	1.10–1.40	0.040	0.16–0.23
1117	0.14–0.20	1.00–1.30	0.040	0.08–0.13
1118	0.14–0.20	1.30–1.60	0.040	0.08–0.13
1119	0.14–0.20	1.00–1.30	0.040	0.24–0.33
1132	0.27–0.34	1.35–1.65	0.040	0.08–0.13
1137	0.32–0.39	1.35–1.65	0.040	0.08–0.13
1139	0.35–0.43	1.35–1.65	0.040	0.13–0.20
1140	0.37–0.44	0.70–1.00	0.040	0.08–0.13
1141	0.37–0.45	1.35–1.65	0.040	0.08–0.13
1144	0.40–0.48	1.35–1.65	0.040	0.24–0.33
1145	0.42–0.49	0.70–1.00	0.040	0.04–0.07
1146	0.42–0.49	0.70–1.00	0.040	0.08–0.13
1151	0.48–0.55	0.70–1.00	0.040	0.08–0.13

TABLE 1 (CONT'D)
GRADE DESIGNATIONS AND CHEMICAL COMPOSITIONS OF CARBON STEEL BARS

Grade Designation	Rephosphorized and Resulfurized Carbon Steels[D,E,H]				
	Carbon	Manganese	Phosphorus	Sulfur	Lead
1211	0.13 max	0.60–0.90	0.07–0.12	0.10–0.15	. . .
1212	0.13 max	0.70–1.00	0.07–0.12	0.16–0.23	. . .
1213	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	. . .
1215	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35	. . .
12L13	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	0.15–0.35
12L14	0.15 max	0.85–1.15	0.04–0.09	0.26–0.35	0.15–0.35
12L15	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35	0.15–0.35

Grade Designation	High-Manganese Carbon Steels[B,C,D,G,H]				
	Former Designation	Carbon	Manganese	Phosphorus, max	Sulfur, max
1513	. . .	0.10–0.16	1.10–1.40	0.040	0.050
1518	. . .	0.15–0.21	1.10–1.40	0.040	0.050
1522	. . .	0.18–0.24	1.10–1.40	0.040	0.050
1524	1024	0.19–0.25	1.35–1.65	0.040	0.050
1525	. . .	0.23–0.29	0.80–1.10	0.040	0.050
1526	. . .	0.22–0.29	1.10–1.40	0.040	0.050
1527	1027	0.22–0.29	1.20–1.50	0.040	0.050
1536	1036	0.30–0.37	1.20–1.50	0.040	0.050
1541	1041	0.36–0.44	1.35–1.65	0.040	0.050
1547	. . .	0.43–0.51	1.35–1.65	0.040	0.050
1548	1048	0.44–0.52	1.10–1.40	0.040	0.050
1551	1051	0.45–0.56	0.85–1.15	0.040	0.050
1552	1052	0.47–0.55	1.20–1.50	0.040	0.050
1561	1061	0.55–0.65	0.75–1.05	0.040	0.050
1566	1066	0.60–0.71	0.85–1.15	0.040	0.050
1572	1072	0.65–0.76	1.00–1.30	0.040	0.050

Grade Designation	Heat Chemical Ranges and Limits, percent			
	Merchant Quality M Series Carbon Steel Bars			
	Carbon	Manganese[F]	Phosphorus, max	Sulfur, max
M 1008	0.10 max	0.25–0.60	0.04	0.05
M 1010	0.07–0.14	0.25–0.60	0.04	0.05
M 1012	0.09–0.16	0.25–0.60	0.04	0.05
M 1015	0.12–0.19	0.25–0.60	0.04	0.05
M 1017	0.14–0.21	0.25–0.60	0.04	0.05
M 1020	0.17–0.24	0.25–0.60	0.04	0.05
M 1023	0.19–0.27	0.25–0.60	0.04	0.05
M 1025	0.20–0.30	0.25–0.60	0.04	0.05
M 1031	0.26–0.36	0.25–0.60	0.04	0.05
M 1044	0.40–0.50	0.25–0.60	0.04	0.05

[A] Maximum unless otherwise indicated.

[B] When silicon is required, the following ranges and limits are commonly specified: 0.10%, max, 0.10% to 0.20%, 0.15% to 0.35%, 0.20% to 0.40%, or 0.30% to 0.60%.

[C] Copper can be specified when required as 0.20% minimum.

[D] When lead is required as an added element to a standard steel, a range of 0.15 to 0.35% inclusive is specified. Such a steel is identified by inserting the letter "L" between the second and third numerals of the grade designation, for example, 10 L 45. A cast or heat analysis is not determinable when lead is added to the ladle stream.

[E] It is not common practice to produce these steels to specified limits for silicon because of its adverse effect on machinability.

[F] Unless prohibited by the purchaser, the manganese content may exceed 0.60% on heat analysis to a maximum of 0.75%, provided the carbon range on heat analysis has the minimum and maximum reduced by 0.01% for each 0.05% manganese over 0.60%.

[G] When boron treatment for killed steels is specified, the steels can be expected to contain 0.0005 to 0.003% boron. If the usual titanium additive is not permitted, the steels can be expected to contain up to 0.005% boron.

[H] The elements bismuth, calcium, selenium, or tellurium may be added as agreed upon between purchaser and supplier.

TABLE 2
GRADE DESIGNATIONS AND CHEMICAL COMPOSITIONS OF ALLOY STEEL BARS

NOTE 1 — Small quantities of certain elements are present in alloy steels which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: copper, 0.35%; nickel, 0.25%; chromium, 0.20%; and molybdenum, 0.06%.

NOTE 2 — Where minimum and maximum sulfur content is shown it is indicative of resulfurized steel.

NOTE 3 — The chemical ranges and limits shown in Table 2 are produced to product analysis tolerances shown in Table 6.

NOTE 4 — Standard alloy steels can be produced with a lead range of 0.15–0.35%. Such steels are identified by inserting the letter "L" between the second and third numerals of the AISI number, for example, 41 L 40. A cast or heat analysis is not determinable when lead is added to the ladle stream.

Grade Designation	Heat Chemical Ranges and Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon[A]	Nickel	Chromium	Molybdenum
1330	0.28–0.33	1.60–1.90	0.035	0.040	0.15 to 0.35	. . .	. . .	. . .
1335	0.33–0.38	1.60–1.90	0.035	0.040	0.15 to 0.35	. . .	. . .	. . .
1340	0.38–0.43	1.60–1.90	0.035	0.040	0.15 to 0.35	. . .	. . .	. . .
1345	0.43–0.48	1.60–1.90	0.035	0.040	0.15 to 0.35	. . .	. . .	. . .
4012	0.09–0.14	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	. . .	0.15–0.25
4023	0.20–0.25	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.20–0.30
4024	0.20–0.25	0.70–0.90	0.035	0.035–0.050	0.15 to 0.35	. . .	. . .	0.20–0.30
4027	0.25–0.30	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.20–0.30
4028	0.25–0.30	0.70–0.90	0.035	0.035–0.050	0.15 to 0.35	. . .	. . .	0.20–0.30
4032	0.30–0.35	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.20–0.30
4037	0.35–0.40	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.20–0.30
4042	0.40–0.45	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.20–0.30
4047	0.45–0.50	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.20–0.30
4118	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.40–0.60	0.08–0.15
4120	0.18–0.23	0.90–1.20	0.035	0.040	0.15 to 0.35	. . .	0.40–0.60	0.13–0.20
4121	0.18–0.23	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.45–0.65	0.20–0.30
4130	0.28–0.33	0.40–0.60	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4135	0.33–0.38	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4137	0.35–0.40	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4140	0.38–0.43	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4142	0.40–0.45	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4145	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4147	0.45–0.50	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4150	0.48–0.53	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	0.15–0.25
4161	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	0.25–0.35
4320	0.17–0.22	0.45–0.65	0.035	0.040	0.15 to 0.35	1.65–2.00	0.40–0.60	0.20–0.30
4340	0.38–0.43	0.60–0.80	0.035	0.040	0.15 to 0.35	1.65–2.00	0.70–0.90	0.20–0.30
E4340	0.38–0.43	0.65–0.85	0.025	0.025	0.15 to 0.35	1.65–2.00	0.70–0.90	0.20–0.30
4419	0.18–0.23	0.45–0.65	0.035	0.040	0.15 to 0.35	. . .	. . .	0.45–0.60
4422	0.20–0.25	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.35–0.45
4427	0.24–0.29	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	. . .	0.35–0.45
4615	0.13–0.18	0.45–0.65	0.035	0.040	0.15 to 0.35	1.65–2.00	. . .	0.20–0.30
4620	0.17–0.22	0.45–0.65	0.035	0.040	0.15 to 0.35	1.65–2.00	. . .	0.20–0.30
4621	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	1.65–2.00	. . .	0.20–0.30
4626	0.24–0.29	0.45–0.65	0.035	0.040	0.15 to 0.35	0.70–1.00	. . .	0.15–0.25
4715	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	0.70–1.00	0.45–0.65	0.45–0.60
4718	0.16–0.21	0.70–0.90	0.035	0.040	0.15 to 0.35	0.90–1.20	0.35–0.55	0.30–0.40
4720	0.17–0.22	0.50–0.70	0.035	0.040	0.15 to 0.35	0.90–1.20	0.35–0.55	0.15–0.25
4815	0.13–0.18	0.40–0.60	0.035	0.040	0.15 to 0.35	3.25–3.75	. . .	0.20–0.30
4817	0.15–0.20	0.40–0.60	0.035	0.040	0.15 to 0.35	3.25–3.75	. . .	0.20–0.30
4820	0.18–0.23	0.50–0.70	0.035	0.040	0.15 to 0.35	3.25–3.75	. . .	0.20–0.30
5015	0.12–0.17	0.30–0.50	0.035	0.040	0.15 to 0.35	. . .	0.30–0.50	. . .
5046	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.20–0.35	. . .
5115	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
5120	0.17–0.22	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
5130	0.28–0.33	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	. . .
5132	0.30–0.35	0.60–0.80	0.035	0.040	0.15 to 0.35	. . .	0.75–1.00	. . .
5135	0.33–0.38	0.60–0.80	0.035	0.040	0.15 to 0.35	. . .	0.80–1.05	. . .
5140	0.38–0.43	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .

TABLE 2 (CONT'D)
GRADE DESIGNATIONS AND CHEMICAL COMPOSITIONS OF ALLOY STEEL BARS

Grade Designation	Heat Chemical Ranges and Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon[A]	Nickel	Chromium	Molybdenum
5145	0.43–0.48	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
5147	0.46–0.51	0.70–0.95	0.035	0.040	0.15 to 0.35	. . .	0.85–1.15	. . .
5150	0.48–0.53	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
5155	0.51–0.59	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
5160	0.56–0.61	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
E50100	0.98–1.10	0.25–0.45	0.025	0.025	0.15 to 0.35	. . .	0.40–0.60	. . .
E51100	0.98–1.10	0.25–0.45	0.025	0.025	0.15 to 0.35	. . .	0.90–1.15	. . .
E52100	0.98–1.10	0.25–0.45	0.025	0.025	0.15 to 0.35	. . .	1.30–1.60	. . .
6118	0.16–0.21	0.50–0.70	0.035	0.040	0.15 to 0.35	. . .	0.50–0.70	(0.10–0.15 V)
6150	0.48–0.53	0.70–0.90	0.035	0.040	0.15 to 0.35	. . .	0.80–1.10	(0.15 min V)
8115	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	0.20–0.40	0.30–0.50	0.08–0.15
8615	0.13–0.18	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8617	0.15–0.20	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8620	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8622	0.20–0.25	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8625	0.23–0.28	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8627	0.25–0.30	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8630	0.28–0.33	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8637	0.35–0.40	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8640	0.38–0.43	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8642	0.40–0.45	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8645	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8650	0.48–0.53	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8655	0.51–0.59	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8660	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.15–0.25
8720	0.18–0.23	0.70–0.90	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.20–0.30
8740	0.38–0.43	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.20–0.30
8822	0.20–0.25	0.75–1.00	0.035	0.040	0.15 to 0.35	0.40–0.70	0.40–0.60	0.30–0.40
9254	0.51–0.59	0.60–0.80	0.035	0.040	1.20–1.60	. . .	0.60–0.80	. . .
9255	0.51–0.59	0.70–0.95	0.035	0.040	1.80–2.20	. . .	. . .	. . .
9259	0.56–0.64	0.75–1.00	0.035	0.040	0.70–1.10	. . .	0.45–0.65	. . .
9260	0.56–0.64	0.75–1.00	0.035	0.040	1.80–2.20	. . .	. . .	. . .
E9310	0.08–0.13	0.45–0.65	0.025	0.025	0.15 to 0.30	3.00–3.50	1.00–1.40	0.08–0.15
Standard Boron Steels[B]								
50B44	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.20–0.60	. . .
50B46	0.44–0.49	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.20–0.35	. . .
50B50	0.48–0.53	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.40–0.60	. . .
50B60	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.40–0.60	. . .
51B60	0.56–0.64	0.75–1.00	0.035	0.040	0.15 to 0.35	. . .	0.70–0.90	. . .
81B45	0.43–0.48	0.75–1.00	0.035	0.040	0.15 to 0.35	0.20–0.40	0.35–0.55	0.08–0.15
94B17	0.15–0.20	0.75–1.00	0.035	0.040	0.15 to 0.35	0.30–0.60	0.30–0.50	0.80–0.15
94B30	0.28–0.33	0.75–1.00	0.035	0.040	0.15 to 0.35	0.30–0.60	0.30–0.50	0.08–0.15

[A] Silicon may be specified by the purchaser as 0.10% maximum. The need for 0.10% maximum generally relates to severe cold-formed parts.
[B] These steels can be expected to contain 0.0005 to 0.003% boron. If the usual titanium additive is not permitted, the steels can be expected to contain up to 0.005% boron.

TABLE 3
HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF CARBON STEEL BARS

Element	Chemical Ranges and Limits, %		
	When Maximum of Specified Elements is:	Range	Lowest Maximum
Carbon [A]	. . .	. . .	0.06
	to 0.12, incl	. . .	. . .
	over 0.12 to 0.26, incl	0.05	. . .
	over 0.25 to 0.40, incl	0.06	. . .
	over 0.40 to 0.55, incl	0.07	. . .
	over 0.55 to 0.80, incl	0.10	. . .
	over 0.80	0.13	. . .
Manganese	. . .	. . .	0.35
	to 0.40, incl	0.15	. . .
	over 0.40 to 0.50, incl	0.20	. . .
	over 0.50 to 1.65, incl	0.30	. . .
Phosphorus	to 0.040, incl	. . .	0.040 [D]
	over 0.040 to 0.08, incl	0.03	. . .
	over 0.08 to 0.13, incl	0.05	. . .
Sulfur	to 0.050, incl	. . .	0.050 [D]
	over 0.050 to 0.09, incl	0.03	. . .
	over 0.09 to 0.15, incl	0.05	. . .
	over 0.15 to 0.23, incl	0.07	. . .
	over 0.23 to 0.50, incl	0.09	. . .
Silicon [B]	. . .	. . .	0.10
	to 0.10, incl	. . .	. . .
	over 0.10 to 0.15, incl	0.08	. . .
	over 0.15 to 0.20, incl	0.10	. . .
	over 0.20 to 0.30, incl	0.15	. . .
	over 0.30 to 0.60, incl	0.20	. . .
Copper	When copper is required 0.20 min is generally used		
Lead [C]	When lead is required, a range of 0.15 to 0.35 is specified		
Bismuth [E]			
Calcium [E]			
Selenium [E]			
Tellurium [E]			

[A] The carbon ranges shown in the column headed "Range" apply when the specified maximum limit for manganese does not exceed 1.10%. When the maximum manganese limit exceeds 1.10%, add 0.01 to the carbon ranges shown above.

[B] It is not common practice to produce a rephosphorized and resulfurized carbon steel to specified limits for silicon because of its adverse effect on machinability.

[C] A cast or heat analysis is not determinable when lead is added to the ladle stream.

[D] For steels produced in merchant quality the phosphorus maximum is 0.04% and the sulfur maximum is 0.05%.

[E] Element specification range as agreed upon between purchaser and supplier.

TABLE 4
HEAT ANALYSIS CHEMICAL RANGES AND LIMITS OF ALLOY STEEL BARS

NOTE 1 — Boron steels can be expected to have 0.0005% minimum boron content.

NOTE 2 — Alloy steels can be produced with a lead range of 0.15–0.35%. A cast or heat analysis is not determinable when lead is added to the ladle stream.

Element	Chemical Ranges and Limits, %			
	When Maximum of Specified Element is:	Open-Hearth or Basic- Oxygen Steel	Electric Furnace Steel	Maximum Limit, % [A]
Carbon	To 0.55, incl	0.05	0.05	
	Over 0.55–0.70, incl	0.08	0.07	
	Over 0.70 to 0.80, incl	0.10	0.09	
	Over 0.80–0.95, incl	0.12	0.11	
	Over 0.95–1.35, incl	0.13	0.12	
Manganese	To 0.60, incl	0.20	0.15	
	Over 0.60–0.90, incl	0.20	0.20	
	Over 0.90–1.05, incl	0.25	0.25	
	Over 1.05–1.90, incl	0.30	0.30	
	Over 1.90–2.10, incl	0.40	0.35	
Phosphorus	Basic open-hearth or basic-oxygen steel			0.035
	Acid open-hearth steel			0.050
	Basic electric-furnace steel			0.025
	Acid electric-furnace steel			0.050
Sulfur	To 0.050, incl	0.015	0.015	
	Over 0.050–0.07, incl	0.02	0.02	
	Over 0.07–0.10, incl	0.04	0.04	
	Over 0.10–0.14, incl	0.05	0.05	
	Basic open-hearth or basic-oxygen steel			0.040
	Acid open-hearth steel			0.050
	Basic electric-furnace steel			0.025
	Acid electric-furnace steel			0.050
Silicon	To 0.20, incl	0.08	0.08	
	Over 0.20–0.30, incl	0.15	0.15	
	Over 0.30–0.60, incl	0.20	0.20	
	Over 0.60–1.00, incl	0.30	0.30	
	Over 1.00–2.20, incl	0.40	0.35	
	Acid steels [B]			
Nickel	To 0.50, incl	0.20	0.20	
	Over 0.50–1.50, incl	0.30	0.30	
	Over 1.50–2.00, incl	0.35	0.35	
	Over 2.00–3.00, incl	0.40	0.40	
	Over 3.00–5.30, incl	0.50	0.50	
	Over 5.30–10.00, incl	1.00	1.00	
Chromium	To 0.40, incl	0.15	0.15	
	Over 0.40–0.90, incl	0.20	0.20	
	Over 0.90–1.05, incl	0.25	0.25	
	Over 1.05–1.60, incl	0.30	0.30	
	Over 1.60–1.75, incl	[C]	0.35	
	Over 1.75–2.10, incl	[C]	0.40	
	Over 2.10–3.99, incl	[C]	0.50	
Molybdenum	To 0.10, incl	0.05	0.05	
	Over 0.10–0.20, incl	0.07	0.07	
	Over 0.20–0.50, incl	0.10	0.10	
	Over 0.50–0.80, incl	0.15	0.15	
	Over 0.80–1.15, incl	0.20	0.20	
Tungsten	To 0.50, incl	0.20	0.20	
	Over 0.50–1.00, incl	0.30	0.30	
	Over 1.00–2.00, incl	0.50	0.50	
	Over 2.00–4.00, incl	0.60	0.60	
Vanadium	To 0.25, incl	0.05	0.05	
	Over 0.25–0.50, incl	0.10	0.10	
Aluminum	Up to 0.10, incl	0.05	0.05	
	Over 0.10–0.20, incl	0.10	0.10	
	Over 0.20–0.30, incl	0.15	0.15	
	Over 0.30–0.80, incl	0.25	0.25	
	Over 0.80–1.30, incl	0.35	0.35	
	Over 1.30–1.80, incl	0.45	0.45	
Copper	To 0.60, incl	0.20	0.20	
	Over 0.60–1.50, incl	0.30	0.30	
	Over 1.50–2.00, incl	0.35	0.35	

[A] Applies to only nonrephosphorized and nonresulfurized steels.

[B] Minimum silicon limit for acid open-hearth or acid electric-furnace alloy steels is 0.15%.

[C] Not normally produced in open-hearth.

TABLE 5
PERMISSIBLE VARIATIONS FOR PRODUCT ANALYSIS OF CARBON STEEL

Element	Limit, or Maximum of Specified Range, %	Over Maximum Limit, %	Under Minimum Limit, %
Carbon[A]	0.25 and under	0.02	0.02
	over 0.25 to 0.55, incl	0.03	0.03
	over 0.55	0.04	0.04
Manganese	0.90 and under	0.03	0.03
	over 0.90 to 1.65, incl	0.06	0.06
Phosphorus[A,B]	basic steels	0.008	. . .
	acid bessemer steel	0.01	0.01
Sulfur[A,B]		0.008	. . .
Silicon	0.35 and under	0.02	0.02
	over 0.35 to 0.60, incl	0.05	0.05
Copper	under minimum only	. . .	0.02
Lead[C]	0.15 to 0.35, incl	0.03	0.03

[A] Rimmed and capped steels are not subject to rejection on product analysis unless misapplication is clearly indicated.

[B] Resulfurized or rephosphorized steels are not subject to rejection on product analysis for these elements unless misapplication is clearly indicted.

[C] Product analysis tolerance for lead applies both over and under to a specified range of 0.15 to 0.35%.

TABLE 6
PERMISSIBLE VARIATIONS FOR PRODUCT ANALYSIS OF ALLOY STEEL

Elements	Limit, or Maximum of Specified Range, %	Permissible Variations Over Maximum Limit or Under Minimum Limit, %
Carbon	0.30 and under	0.01
	over 0.30 to 0.75, incl	0.02
	over 0.75	0.03
Manganese	0.90 and under	0.03
	over 0.90 to 2.10, incl	0.04
Phosphorus	over maximum only	0.005
Sulfur	0.060 and under	0.005
Silicon	0.40 and under	0.02
	over 0.40 to 2.20, incl	0.05
Nickel	1.00 and under	0.03
	over 1.00 to 2.00, incl	0.05
	over 2.00 to 5.30, incl	0.07
	over 5.30 to 10.00, incl	0.10
Chromium	0.90 and under	0.03
	over 0.90 to 2.10, incl	0.05
	over 2.10 to 3.99, incl	0.10
Molybdenum	0.20 and under	0.01
	over 0.20 to 0.40, incl	0.02
	over 0.40 to 1.15, incl	0.03
Vanadium	0.10 and under	0.01
	over 0.10 to 0.25, incl	0.02
	over 0.25 to 0.50, incl	0.03
	minimum value specified, under minimum limit only	0.01
Tungsten	1.00 and under	0.04
	over 1.00 to 4.00, incl	0.08
Aluminum	0.10 and under	0.03
	over 0.10 to 0.20, incl	0.04
	over 0.20 to 0.30, incl	0.05
	over 0.30 to 0.80, incl	0.07
	over 0.80 to 1.80, incl	0.10
Lead[A]	0.15 to 0.35, incl	0.03
Copper	to 1.00 incl	0.03
	over 1.00 to 2.00, incl	0.05

[A] Product analysis tolerance for lead applies both over and under to a specified range of 0.15 to 0.35%.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order.

S1. Flat Bar Thickness Tolerances

S1.1 When flat bars are specified in metric units to a thickness under tolerance of 0.3 mm, the thickness tolerance of Table S1.1 shall apply.

TABLE S1.1
THICKNESS AND WIDTH TOLERANCES FOR HOT-WROUGHT SQUARE-EDGE AND ROUND-EDGE FLAT BARS ORDERED TO 0.3 MM UNDER TOLERANCE[A]

	Tolerances over Specified Thickness for Thickness Given, mm					Tolerance from Specified Width, mm	
Specified Width, mm	Over 6 to 12, incl	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 75, incl	Over 75	Over	Under
To 25, incl	. . .	. . .	. . .	. . .	. . .	0.5	0.5
Over 25 to 50, incl	. . .	0.5	1.3	. . .	. . .	1.0	1.0
Over 50 to 100, incl	0.5	0.7	1.3	2.1	2.1	1.5	1.0
Over 100 to 150, incl	0.5	0.7	1.3	2.1	2.1	2.5	1.5
Over 150 to 200, incl	0.5	1.0	1.3	2.1	2.9	3.0	2.5

[A] When a square is held against a face and an edge of a square-edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.

NOTE — Tolerance under specified thickness 0.3 mm.

ANNEXES

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC. — INCH-POUND UNITS

A1.1 Listed below are permissible variations in dimensions expressed in inch-pound units of measurements.

TABLE A1.1
PERMISSIBLE VARIATIONS IN CROSS SECTION FOR HOT-WROUGHT ROUND, SQUARE, AND ROUND-CORNERED SQUARE BARS OF STEEL

Specified Size, in.	Permissible Variation from Specified Size, in.[A] Over	Permissible Variation from Specified Size, in.[A] Under	Out-of-Round or Out-of-Square, in.[B]
To 5/16, incl	0.005	0.005	0.008
Over 5/16 to 7/16, incl	0.006	0.006	0.009
Over 7/16 to 5/8, incl	0.007	0.007	0.010
Over 5/8 to 7/8, incl	0.008	0.008	0.012
Over 7/8 to 1, incl	0.009	0.009	0.013
Over 1 to 1 1/8, incl	0.010	0.010	0.015
Over 1 1/8 to 1 1/4, incl	0.011	0.011	0.016
Over 1 1/4 to 1 3/8, incl	0.012	0.012	0.018
Over 1 3/8 to 1 1/2, incl	0.014	0.014	0.021
Over 1 1/2 to 2, incl	1/64	1/64	0.023
Over 2 to 2 1/2, incl	1/32	0	0.023
Over 2 1/2 to 3 1/2, incl	3/64	0	0.035
Over 3 1/2 to 4 1/2, incl	1/16	0	0.046
Over 4 1/2 to 5 1/2, incl	5/64	0	0.058
Over 5 1/2 to 6 1/2, incl	1/8	0	0.070
Over 6 1/2 to 8 1/4, incl	5/32	0	0.085
Over 8 1/4 to 9 1/2, incl	3/16	0	0.100
Over 9 1/2 to 10, incl	1/4	0	0.120

[A] Steel bars are regularly cut to length by shearing or hot sawing, which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

[B] Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same cross section. Out-of-square is the difference in the two dimensions at the same cross section of a square bar between opposite faces.

TABLE A1.2
PERMISSIBLE VARIATIONS IN CROSS SECTION FOR HOT-WROUGHT HEXAGONAL BARS OF STEEL

Specified Sizes Between Opposite Sides, in.	Permissible Variations from Specified Size, in.[A] Over	Permissible Variations from Specified Size, in.[A] Under	Out-of-Hexagon (Carbon Steel and Alloy Steel) or Out-of-Octagon (Alloy Steel), in.[B]
To 1/2, incl	0.007	0.007	0.011
Over 1/2 to 1, incl	0.010	0.010	0.015
Over 1 to 1 1/2, incl	0.021	0.013	0.025
Over 1 1/2 to 2, incl	1/32	1/64	1/32
Over 2 to 2 1/2, incl	3/64	1/64	3/64
Over 2 1/2 to 3 1/2, incl	1/16	1/64	1/16
Over 3 1/2 to 4 1/16, incl	5/64	1/64	5/64

[A] Steel bars are regularly cut to length by shearing or hot sawing, which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

[B] Out-of-hexagon or out-of-octagon is the greatest difference between any two dimensions at the same cross section between opposite faces.

TABLE A1.3
PERMISSIBLE VARIATIONS IN THICKNESS AND WIDTH FOR HOT-WROUGHT SQUARE EDGE AND ROUND EDGE FLAT BARS[A]

Specified Width, in.	Permissible Variations in Thickness, for Thickness Given, Over and Under, in.[B]							Permissible Variations in Width, in.	
	0.203 to 0.230, excl	0.230 to 1/4, excl	1/4 to 1/2, incl	Over 1/2 to 1, incl	Over 1 to 2, incl	Over 2 to 3, incl	Over 3	Over	Under
To 1, incl	0.007	0.007	0.008	0.010	. . .	. . .	. . .	1/64	1/64
Over 1 to 2, incl	0.007	0.007	0.012	0.015	1/32	. . .	. . .	1/32	1/32
Over 2 to 4, incl	0.008	0.008	0.015	0.020	1/32	3/64	3/64	1/16	1/32
Over 4 to 6, incl	0.009	0.009	0.015	0.020	1/32	3/64	3/64	3/32	1/16
Over 6 to 8, incl	[C]	0.015	0.016	0.025	1/32	3/64	1/16	1/8	3/32

[A] When a square is held against a face and an edge of a square edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.

[B] Steel bars are regularly cut to length by shearing or hot sawing, which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

[C] Flats over 6 to 8 in., incl, in width, are not available as hot-wrought steel bars in thickness under 0.230 in.

TABLE A1.4
PERMISSIBLE VARIATIONS IN THICKNESS, LENGTH, AND OUT-OF-SQUARE FOR HOT-WROUGHT BAR SIZE ANGLES OF CARBON STEEL

Specified Length of Leg, in.[A]	Permissible Variations in Thickness, for Thicknesses Given, Over and Under, in.			Permissible Variations for Length of Leg, Over and Under, in.
	To 3/16, incl	Over 3/16 to 3/8, incl	Over 3/8	
To 1, incl	0.008	0.010	. . .	1/32
Over 1 to 2, incl	0.010	0.010	0.012	3/64
Over 2 to 3, excl	0.012	0.015	0.015	1/16

[A] The longer leg of an unequal angle determines the size for tolerance. The out-of-square tolerance in either direction is 1 1/2°.

TABLE A1.5
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HOT-WROUGHT BAR SIZE CHANNELS OF CARBON STEEL

Specified Size of Channel, in.	Permissible Variations in Size, Over and Under, in.				Out-of-Square if Either Flange, in./in. of Flange Width
	Depth of Section[A]	Width of Flanges[A]	Thickness of Web for Thickness Given		
			To 3/16, incl	Over 3/16	
To 1 1/2, incl	1/32	1/32	0.010	0.015	1/32
Over 1 1/2 to 3, excl	1/16	1/16	0.015	0.020	1/32

[A] Measurements for depth of section and width of flanges are over-all.

[B] For channels 5/8 in. and under in depth, the out-of-square tolerance is 3/64 in./in. of depth.

TABLE A1.6
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HOT-WROUGHT BAR SIZE TEES OF CARBON STEEL

Specified Size of Tee, in.[A]	Permissible Variations in Size, in.						
	Width or Depth[B]		Thickness of Flange		Thickness of Stem		Stem out-of-Square[C]
	Over	Under	Over	Under	Over	Under	
To 1 1/4, incl	3/64	3/64	0.010	0.010	0.005	0.020	1/32
Over 1 1/4 to 2, incl	1/16	1/16	0.012	0.012	0.010	0.020	1/16
Over 2 to 3, excl	3/32	3/32	0.015	0.015	0.015	0.020	3/32

[A] The longer member of the unequal tee determines the size for tolerances.

[B] Measurements for both width and depth are over-all.

[C] Step out-of-square is the variation from its true position of the center line of the stem measured at the point.

TABLE A1.7
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HALF-ROUND, OVALS, HALF-OVALS, AND OTHER SPECIAL BAR SIZE SECTIONS

Due to mill facilities, tolerances on half-rounds, ovals, half-ovals, and other special bar size sections vary among the manufacturers and such tolerances should be negotiated between the manufacturer and the purchaser.

TABLE A1.8
PERMISSIBLE VARIATIONS IN LENGTH FOR HOT-WROUGHT ROUNDS, SQUARES, HEXAGONS, FLATS, AND BAR SIZE SECTIONS OF STEEL

Specified Size of Rounds, Squares, and Hexagons, in.	Specified Size of Flats, in.		Permissible Variations Over Specified Length, in.[A]				
	Thickness	Width	5 to 10 ft, excl	10 to 20 ft, excl	20 to 30 ft, excl	30 to 40 ft, excl	40 to 60 ft, excl
Mill Shearing							
To 1, incl	to 1, incl	to 3, incl	1/2	3/4	1 1/4	1 3/4	2 1/4
Over 1 to 2, incl	over 1	to 3, incl	5/8	1	1 1/2	2	2 1/2
	to 1, incl	over 3 to 6, incl	5/8	1	1 1/2	2	2 1/2
Over 2 to 5, incl	over 1	over 3 to 6, incl	1	1 1/2	1 3/4	2 1/4	2 3/4
Over 5 to 10, incl	. . .	. . .	2	2 1/2	2 3/4	3	3 1/4
	0.230 to 1, incl	over 6 to 8, incl	3/4	1 1/4	1 3/4	3 1/2	4
	over 1 to 3, incl	over 6 to 8, incl	1 1/4	1 3/4	2	3 1/2	4
Bar Size Sections	. . .	. . .	5/8	1	1 1/2	2	2 1/2
Hot Sawing							
2 to 5, incl	1 and over	3 and over	[B]	1 1/2	1 3/4	2 1/4	2 3/4
Over 5 to 10, incl	. . .	. . .	[B]	2 1/2	2 3/4	3	3 1/4

[A] No permissible variations under.
[B] Smaller sizes and shorter lengths are not hot sawed.

TABLE A1.9
PERMISSIBLE VARIATIONS IN LENGTH FOR RECUTTING OF BARS MEETING SPECIAL STRAIGHTNESS TOLERANCES

Sizes of Rounds, Squares, Hexagons, Width of Flats and Maximum Dimension of Other Sections, in.[A]	Tolerances Over Specified Length, in.[A]	
	To 12 ft, incl	Over 12 ft
To 3, incl	1/4	5/16
Over 3 to 6, incl	5/16	7/16
Over 6 to 8, incl	7/16	9/16
Rounds over 8 to 10, incl	9/16	11/16

[A] No tolerance under.

TABLE A1.10
PERMISSIBLE VARIATIONS IN STRAIGHTNESS FOR HOT-WROUGHT BARS AND BAR SIZE SECTIONS OF STEEL[A]

Standard tolerances	1/4 in. in any 5 ft or (1/4 in. × length in ft)/5
Special tolerances	1/8 in. in any 5 ft or (1/8 in. × length in ft)/5

[A] Because of warpage, straightness tolerances do not apply to bars if any subsequent heating operation or controlled cooling has been performed.

TABLE A1.11
SIZE TOLERANCES FOR COLD-FINISHED CARBON STEEL BARS, COLD DRAWN OR TURNED AND POLISHED[A]

Size, in.[B]	Maximum of Carbon Range 0.28% or less	Maximum of Carbon Range Over 0.28% to 0.55%, incl	Maximum of Carbon Range to 0.55%, incl, Stress Relieved or Annealed after Cold Finishing	Maximum of Carbon Range Over 0.55% or All Grades Quenched and Tempered or Normalized and Tempered before Cold Finishing
	All tolerances are in inches[B] and are minus[C]			
Rounds — Cold Drawn (to 4 in.) or Turned and Polished				
To 1½, incl	0.002	0.003	0.004	0.005
Over 1½ to 2½, incl	0.003	0.004	0.005	0.006
Over 2½ to 4, incl	0.004	0.005	0.006	0.007
Over 4 to 6, incl	0.005	0.006	0.007	0.008
Over 6 to 8, incl	0.006	0.007	0.008	0.009
Over 8 to 9, incl	0.007	0.008	0.009	0.010
Hexagons				
To ¾, incl	0.002	0.003	0.004	0.006
Over ¾ to 1½, incl	0.003	0.004	0.005	0.007
Over 1½ to 2½, incl	0.004	0.005	0.006	0.008
Over 2½ to 3⅛, incl	0.005	0.006	0.007	0.009
Over 3⅛ to 4, incl	0.005	0.006	. . .	. . .
Squares[C]				
To ¾, incl	0.002	0.004	0.005	0.007
Over ¾ to 1½, incl	0.003	0.005	0.006	0.008
Over 1½ to 2½, incl	0.004	0.006	0.007	0.009
Over 2½ to 4, incl	0.006	0.008	0.009	0.011
Over 4 to 5, incl	0.010	. . .	. . .	. . .
Over 5 to 6, incl	0.014	. . .	. . .	. . .
Flats[D]				
Width,[B] in.				
To ¾, incl	0.003	0.004	0.006	0.008
Over ¾ to 1½, incl	0.004	0.005	0.008	0.010
Over 1½ to 3, incl	0.005	0.006	0.010	0.012
Over 3 to 4, incl	0.006	0.008	0.011	0.016
Over 4 to 6, incl	0.008	0.010	0.012	0.020
Over 6	0.013	0.015		

[A] This table includes tolerances for bars that have been annealed, spheroidize annealed, normalized, normalized and tempered, or quenched and tempered before cold finishing. This table does not include tolerances for bars that are annealed, spheroidize annealed, normalized, normalized and tempered, or quenched and tempered after cold finishing; the producer should be consulted for tolerances for such bars.

[B] Width governs the tolerances for both width and thickness of flats. For example, when the maximum of carbon range is 0.28% or less, for a flat 2 in. wide and 1 in. thick, the width tolerance is 0.005 in. and the thickness tolerance is the same, namely, 0.005 in.

[C] Standard manufacturing practice is a shear cut for cold drawn bars (size limits vary by producer) which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

[D] Tolerances may be ordered all plus, or distributed plus and minus with the sum equivalent to the tolerances listed.

TABLE A1.12
SIZE TOLERANCES FOR COLD FINISHED ROUND BARS COLD DRAWN, GROUND AND POLISHED OR TURNED, GROUND AND POLISHED

Size, in. Cold Drawn, Ground and Polished	Turned, Ground and Polished	Tolerances from Specified Size, Minus Only, in.
To 1½, incl	To 1½, incl	0.001
Over 1½ to 2½, excl	Over 1½ to 2½, excl	0.0015
2½ to 3, incl	2½ to 3, incl	0.002
Over 3 to 4, incl	Over 3 to 4, incl	0.003
. . .	Over 4 to 6, incl	0.004[A]
. . .	Over 6	0.005[A]

[A] For non-resulfurized steels (steels specified to maximum sulphur limits under 0.08%), or for steels thermally treated, the tolerance is increased by 0.001 in.

TABLE A1.13
SIZE TOLERANCE FOR COLD-FINISHED ALLOY STEEL BARS, COLD DRAWN, OR TURNED AND POLISHED

Size in.[A]	Maximum of Carbon Range 0.28% or less	Maximum of Carbon Range Over 0.28% to 0.55%, incl	Maximum of Carbon Range to 0.55%, incl, Stress Relieved or Annealed after Cold Finishing	Maximum of Carbon Range Over 0.55% With or Without Stress Relieving or Annealing after Cold Finishing. Also all Carbons, Quenched and Tempered (Heat Treated), or Normalized and Tempered, before Cold Finishing
	All tolerances are in inches and are minus[B]			
Rounds — Cold Drawn (to 4 in.) or Turned and Polished				
To 1, incl, in coils	0.002	0.003	0.004	0.005
Cut Lengths:				
To 1½, incl	0.003	0.004	0.005	0.006
Over 1½ to 2½, incl	0.004	0.005	0.006	0.007
Over 2½ to 4, incl	0.005	0.006	0.007	0.008
Over 4 to 6, incl	0.006	0.007	0.008	0.009
Over 6 to 8, incl	0.007	0.008	0.009	0.010
Over 8 to 9, incl	0.008	0.009	0.010	0.011
Hexagons				
To ¾, incl	0.003	0.004	0.005	0.007
Over ¾ to 1½, incl	0.004	0.005	0.006	0.008
Over 1½ to 2½, incl	0.005	0.006	0.007	0.009
Over 2½ to 3⅛, incl	0.006	0.007	0.008	0.010
Over 3⅛ to 4, incl	0.006	. . .	. . .	. . .
Squares				
To ¾, incl	0.003	0.005	0.006	0.008
Over ¾ to 1½, incl	0.004	0.006	0.007	0.009
Over 1½ to 2½, incl	0.005	0.007	0.008	0.010
Over 2½ to 4, incl	0.007	0.009	0.010	0.012
Over 4 to 5, incl	0.011	. . .	. . .	. . .
Flats[A]				
To ¾, incl	0.004	0.005	0.007	0.009
Over ¾ to 1½, incl	0.005	0.006	0.009	0.011
Over 1½ to 3, incl	0.006	0.007	0.011	0.013
Over 3 to 4, incl	0.007	0.009	0.012	0.017
Over 4 to 6, incl	0.009	0.011	0.013	0.021
Over 6	0.014	. . .	. . .	. . .

[A] Width governs the tolerances for both width and thickness of flats. For example, when the maximum of carbon range is 0.28% or less, for a flat 2 in. wide and 1 in. thick, the width tolerance is 0.006 in. and the thickness tolerance is the same, namely 0.006 in.

[B] Standard manufacturing practice is a shear cut for cold drawn bars (size limits vary by producer) which can cause end distortion resulting in those portions of the bar being outside the applicable size tolerance. When this end condition is objectionable, a machine cut end should be considered.

TABLE A1.14
STRAIGHTNESS TOLERANCES FOR COLD FINISHED BARS[A,B]

		Straightness Tolerances, in. (Maximum Deviation) from Straightness in any 10-ft Portion of the Bar			
		Maximum of Carbon Range, 0.28% or Less		Maximum of Carbon Range Over 0.28% and All Grades Thermally Treated	
Size, in.	Length, ft	Rounds	Squares, Hexagons, and Octagons	Rounds	Squares, Hexagons, and Octagons
Less than 5/8	less than 15	1/8	3/16	3/16	1/4
Less than 5/8	15 and over	1/8	5/16	5/16	3/8
5/8 and over	less than 15	1/16	1/8	1/8	3/16
5/8 and over	15 and over	1/8	3/16	3/16	1/4

[A] The foregoing tolerances are based on the following method of measuring straightness: Departure from straightness is measured by placing the bar on a level table so that the arc or departure from straightness is horizontal, and the depth of the arc is measured with a feeler gage and a straightedge.

[B] It should be recognized that straightness is a perishable quality and may be altered by mishandling. The preservation of straightness in cold-finished bars requires the utmost care in subsequent handling. Specific straightness tolerances are sometimes required for carbon and alloy steels in which case the purchaser should inform the manufacturer of the straightness tolerances and the methods to be used in checking the straightness.

A2. DIMENSIONAL TOLERANCES — SI UNITS

A2.1 Listed herein are dimensional tolerances expressed in SI units.

TABLE A2.1
TOLERANCES IN SECTIONAL DIMENSIONS FOR ROUND AND SQUARE BARS AND ROUND-CORNERED SQUARE BARS

Size, mm	Tolerance from Specified Size, Over and Under, mm or %[B]	Out-of-Round, or Out-of-Square Section,[A] mm or %[B]
To 7, incl	0.13 mm	0.20 mm
Over 7 to 11, incl	0.15 mm	0.22 mm
Over 11 to 15, incl	0.18 mm	0.27 mm
Over 15 to 19, incl	0.20 mm	0.30 mm
Over 19 to 250, incl	1%	1.5%

[A] Out-of-round is the difference between the maximum and the minimum diameters of the bar, measured at the same cross section. Out-of-square is the difference in the two dimensions at the same cross section of a square bar between opposite faces.

[B] The tolerance shall be rounded to the nearest tenth of a millimetre after calculation.

TABLE A2.2
TOLERANCES IN CROSS SECTION FOR HOT-WROUGHT HEXAGONAL AND OCTAGONAL STEEL BARS

Specified Size Between Opposite Sides, mm	Tolerance from Specified Size, mm		Out of Hexagon or Out of Octagon, mm[A]
	Over	Under	
To 13, incl	0.18	0.18	0.3
Over 13 to 25, incl	0.25	0.25	0.4
Over 25 to 40, incl	0.55	0.35	0.6
Over 40 to 50, incl	0.8	0.40	0.8
Over 50 to 65, incl	1.2	0.40	1.2
Over 65 to 80, incl	1.6	0.40	1.6
Over 80 to 100, incl	2.0	0.40	2.0

[A] Out of hexagon or out of octagon is the greatest difference between any two dimensions at the cross section between opposite faces.

TABLE A2.3
THICKNESS AND WIDTH TOLERANCES FOR HOT-WROUGHT SQUARE-EDGE AND ROUND-EDGE FLAT BARS[A,B]

Specified Width, mm	Tolerances from Specified Thickness for Thickness Given Over and Under, mm						Tolerances from Specified Width, mm	
	Over 5 to 6, incl	Over 6 to 12, incl	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 75	Over 75	Over	Under
To 25, incl	0.18	0.20	0.25	. . .	. . .	. . .	0.5	0.5
Over 25 to 50, incl	0.18	0.30	0.40	0.8	. . .	. . .	1.0	1.0
Over 50 to 100, incl	0.20	0.40	0.50	0.8	1.2	1.2	1.5	1.0
Over 100 to 150, incl	0.25	0.40	0.50	0.8	1.2	1.2	2.5	1.5
Over 150 to 200, incl	[A]	0.40	0.65	0.8	1.2	1.6	3.0	2.5

[A] When a square is held against a face and an edge of a square edge flat bar, the edge shall not deviate by more than 3° or 5% of the thickness.
[B] Flats over 150 to 200 mm, incl in width are not available as hot-wrought bars in thickness 6 mm and under.

TABLE A2.4
THICKNESS, LENGTH, AND OUT-OF-SQUARE TOLERANCES FOR HOT-WROUGHT BAR SIZE ANGLES

Specified Length of Leg, mm[A,B]	Tolerances in Thickness for Thickness Given, Over and Under, mm			Tolerances for Length of Leg Over and Under, mm
	To 5, incl	Over 5 to 10, incl	Over 10	
To 50, incl	0.2	0.2	0.3	1
Over 50 to 75, excl	0.3	0.4	0.4	2

[A] The longer leg of an unequal angle determines the size for tolerance.
[B] Out of square tolerances in either direction is 1½° = 0.026 mm/mm.

TABLE A2.5
DIMENSIONAL TOLERANCES FOR HOT-WROUGHT BAR SIZE CHANNELS

Specified Size of Channel, mm	Tolerances in Size, Over and Under, mm				
	Depth of Section[A]	Width of Flanges[A]	Thickness of Web		Out of Square of Either Flange per mm of Flange Width,[B] mm
			To 5, incl	Over 5	
To 40, incl	1	1	0.2	0.4	0.03
Over 40 to 75, excl	2	2	0.4	0.5	0.03

[A] Measurements for depth of section and width of flanges are overall.
[B] For channels 16 mm and under in depth, out of square tolerance is 0.05 mm/mm.

TABLE A2.6
DIMENSIONAL TOLERANCES FOR HOT-WROUGHT BAR SIZE TEES

Specified Size of Tee,[A] mm	Tolerances in Size, mm						
	Width or Depth,[B]		Thickness of Flange		Thickness of Stem		Stem Out of Square[C]
	Over	Under	Over	Under	Over	Under	
To 30, incl	1	1	0.2	0.2	0.1	0.5	1
Over 30 to 50, incl	2	2	0.3	0.3	0.2	0.5	2
Over 50 to 75, excl	2	2	0.4	0.4	0.4	0.5	2

[A] The longer member of the unequal tee determines the size for tolerances.
[B] Measurements for width and depth are over all.
[C] Stem out of square is the tolerance from its true position of the center line of the stem measured at the point.

TABLE A2.7
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR HALF-ROUNDS, OVALS, HALF-OVALS, AND OTHER SPECIAL BAR SIZE SECTIONS

Due to mill facilities, tolerances on half-rounds, ovals, and other special bar size sections vary among the manufacturers and such tolerances should be negotiated between the manufacturer and the purchaser.

TABLE A2.8
LENGTH TOLERANCES FOR HOT-WROUGHT ROUNDS, SQUARES, HEXAGONS, OCTAGONS, FLATS, AND BAR SIZE SECTIONS

Specified Size of Rounds, Squares, Hexagons and Octagons, mm	Specified Size of Flats, mm		Tolerances over Specified Length, mm[A]				
	Thickness	Width	1500 to 3000, excl	3000 to 6000, excl	6000 to 9000, excl	9000 to 12 000, excl	12 000 to 18 000, excl
Hot Shearing							
To 25, incl	to 25, incl	to 75, incl	15	20	35	45	60
Over 25 to 50, incl	over 25	to 75, incl	15	25	40	50	65
	to 25, incl	over 75 to 150, incl	15	25	40	50	65
Over 50 to 125, incl	over 25	over 75 to 150, incl	25	40	45	60	70
Over 125 to 250, incl	. . .	. . .	50	65	70	75	85
Bar Size Sections	over 6 to 25, incl	over 150 to 200, incl	20	30	45	90	100
	over 25 to 75, incl	over 150 to 200, incl	30	45	50	90	100
	. . .	. . .	15	25	40	50	65
Hot Sawing							
50 to 125, incl	25 and over	75 and over	[B]	40	45	60	70
Over 125 to 250, incl	. . .	. . .	[B]	65	70	75	85

[A] No tolerance under.
[B] Smaller sizes and shorter lengths are not hot sawed.

TABLE A2.9
LENGTH TOLERANCES FOR RECUTTING OF BARS MEETING SPECIAL STRAIGHTNESS TOLERANCES

Sizes of Rounds, Squares, Hexagons, Octagons, Widths of Flats and Maximum Dimensions of Other Sections, mm	Tolerances over Specified Length, mm[A]	
	To 3700 mm, incl	Over 3700 mm
To 75, incl	6	8
Over 75 to 150, incl	8	11
Over 150 to 200, incl	11	14
Rounds over 200 to 250, incl	14	18

[A] No tolerance under.

TABLE A2.10
STRAIGHTNESS TOLERANCES FOR HOT-WROUGHT BARS AND BAR SIZE SECTIONS[A]

Standard tolerances	6 mm if any 1500 mm or (length in mm/250)[B]
Special tolerances	3 mm in any 1500 mm or (length in mm/500)[B]

[A] Because of warpage, straightness tolerances do not apply to bars if any subsequent heating operation or controlled cooling has been performed.
[B] Round to the nearest whole millimetre.

TABLE A2.11
SIZE TOLERANCES FOR COLD-FINISHED CARBON STEEL BARS, COLD DRAWN OR TURNED AND POLISHED[A]

Size, mm	Tolerances from Specified Size, Under Only, mm			
	Maximum of Carbon Range 0.28 or Less	Maximum of Carbon Range Over 0.28 to 0.55, incl	Maximum of Carbon Range to 0.55%, incl Stress Relief or Annealed After Cold Finishing	Maximum of Carbon Range Over 0.55% or All Grades Quenched and Tempered or Normalized Before Cold Finishing
Rounds — Cold Drawn (to 100 mm in size) or Turned and Polished				
To 40, incl	0.05	0.08	0.10	0.13
Over 40 to 60, incl	0.08	0.10	0.13	0.15
Over 60 to 100, incl	0.10	0.13	0.15	0.18
Over 100 to 150, incl	0.13	0.15	0.18	0.20
Over 150 to 200, incl	0.15	0.18	0.20	0.23
Over 200 to 230, incl	0.18	0.20	0.23	0.25
Hexagons — Cold Drawn				
Up to 20, incl	0.05	0.08	0.10	0.15
Over 20 to 40, incl	0.08	0.10	0.13	0.18
Over 40 to 60, incl	0.10	0.13	0.15	0.20
Over 60 to 80, incl	0.13	0.15	0.18	0.23
Over 80 to 100, incl	0.13	0.15	. . .	
Squares— Cold Drawn[C]				
Up to 20, incl	0.05	0.10	0.13	0.18
Over 20 to 40, incl	0.08	0.13	0.15	0.20
Over 40 to 60, incl	0.10	0.15	0.18	0.23
Over 60 to 100, incl	0.15	0.20	0.23	0.28
Over 100 to 130, incl	0.25	. . .	. . .	. . .
Over 130 to 150, incl	0.36	. . .	. . .	. . .
Flats — Cold Drawn[B,C]				
To 20, incl	0.08	0.10	0.15	0.20
Over 20 to 40, incl	0.10	0.13	0.20	0.25
Over 40 to 80, incl	0.13	0.15	0.25	0.30
Over 80 to 100, incl	0.15	0.20	0.28	0.40
Over 100 to 150, incl	0.20	0.25	0.30	0.50
Over 150	0.33	0.38	. . .	. . .

[A] This table includes tolerances for bars that have been annealed, spheroidize annealed, normalized, normalized and tempered, or quenched and tempered before cold finishing. This table does not include tolerances for bars that are annealed, spheroidize annealed, normalized, normalized and tempered, or quenched and tempered after cold finishing; the producer should be consulted for tolerances for such bars.

[B] Width governs the tolerance for both width and thickness of flats, for example, when the maximum of carbon range is 0.28% or less for a flat 50 mm wide and 25 mm thick, the width tolerance is 0.13 mm and the thickness is the same, namely, 0.13 mm.

[C] Tolerances may be ordered all plus, or distributed plus and minus with the sum equivalent to the tolerances listed.

TABLE A2.12
SIZE TOLERANCES FOR COLD-FINISHED ROUND BARS, COLD DRAWN, GROUND AND POLISHED, OR TURNED, GROUND AND POLISHED

Size, mm		Tolerances from, Specified Size, Minus Only, mm
Cold Drawn, Ground, and Polished	Turned, Ground, and Polished	
To 40, incl	To 40, incl	0.03
Over 40 to 60, incl	Over 40 to 60, incl	0.04
Over 60 to 80, incl	Over 60 to 80, incl	0.05
Over 80 to 100, incl	Over 80 to 100, incl	0.08
. . .	Over 100 to 150, incl	0.10[A]
. . .	Over 150	0.13[A]

[A] For nonresulphurized steels (steels specified to maximum sulfur limits under 0.08%) or for steels thermally treated, the tolerance is increased by 0.03 mm.

TABLE A2.13
SIZE TOLERANCES FOR COLD-FINISHED ALLOY STEEL BARS, COLD DRAWN OR TURNED AND POLISHED[A]

Size, mm	Tolerances from Specified Size, Under Only, mm			
	Maximum of Carbon Range 0.28 or less	Maximum of Carbon Range Over 0.28 to 0.55, incl	Maximum of Carbon Range to 0.55%, incl Stress Relief or Annealed After Cold Finishing	Maximum of Carbon Range Over 0.55% or All Grades Quenched and Tempered or Normalized Before Cold Finishing
Rounds — Cold Drawn (to 100 mm in size) or Turned and Polished				
To 25, incl, in coils	0.05	0.08	0.10	0.13
Cut Lengths				
To 40, incl	0.08	0.10	0.13	0.15
Over 40 to 60, incl	0.10	0.13	0.15	0.18
Over 60 to 100, incl	0.13	0.15	0.18	0.20
Over 100 to 150, incl	0.15	0.18	0.20	0.23
Over 150 to 200, incl	0.18	0.20	0.23	0.25
Over 200 to 230, incl	0.20	0.23	0.25	0.28
Hexagons — Cold Drawn				
Up to 20, incl	0.08	0.10	0.13	0.18
Over 20 to 40, incl	0.10	0.13	0.15	0.20
Over 40 to 60, incl	0.13	0.15	0.18	0.23
Over 60 to 80, incl	0.15	0.18	0.20	0.25
Over 80 to 100, incl	0.15	. . .	. . .	. . .
Squares — Cold Drawn				
Up to 20, incl	0.08	0.13	0.15	0.20
Over 20 to 40, incl	0.10	0.15	0.18	0.23
Over 40 to 60, incl	0.13	0.18	0.20	0.25
Over 60 to 100, incl	0.18	0.23	0.25	0.30
Over 100 to 130, incl	0.28	0.23	0.25	0.30
Flats — Cold Drawn[B]				
Width[B]				
To 20, incl	0.10	0.13	0.18	0.23
Over 20 to 40, incl	0.13	0.15	0.23	0.28
Over 40 to 80, incl	0.15	0.18	0.28	0.33
Over 80 to 100, incl	0.18	0.23	0.30	0.43
Over 100 to 150, incl	0.23	0.28	0.33	0.52
Over 150	0.36	. . .	. . .	. . .

[A] This table includes tolerances for bars that have been annealed, spheriodize annealed, normalized, normalized and tempered, or quenched and tempered before cold finishing. This table does not include tolerances for bars that are annealed, spheriodize annealed, normalized, normalized and tempered, or quenched and tempered after cold finishing; the producer should be consulted for tolerances for such bars.

[B] Width governs the tolerance for both width and thickness of flats. For example, when the maximum of carbon range is 0.28% or less for a flat 50 mm wide and 25 mm thick, the width tolerance is 0.13 mm and the thickness tolerance is the same, namely 0.13 mm.

TABLE A2.14
STRAIGHTNESS TOLERANCES FOR COLD-FINISHED BARS[A,B]

Note — All grades quenched and tempered or normalized and tempered to Brinnell 302 maximum *before* cold finishing and all grades stress relieved or annealed *after* cold finishing. Straightness tolerances are not applicable to bars having Brinnell hardness exceeding 302.

		Straightness Tolerances, mm (Maximum Deviation) from Straightness in any 3000 mm Portion of the Bar			
		Maximum of Carbon Range, 0.28% or less		Maximum of Carbon Range over 0.28% and all Grades Thermally Treated	
Size, mm	Length, mm	Rounds	Squares, Hexagons, and Octagons	Rounds	Squares, Hexagons, and Octagons
Less than 16	Less than 4500	3	5	5	6
Less than 16	4500 and over	3	8	8	10
16 and over	Less than 4500	2	3	3	5
16 and over	4500 and over	3	5	5	6

[A] The foregoing tolerances are based on the following method of measuring straightness; departure from straightness is measured by placing the bar on a level table so that the arc or departure from straightness is horizontal, and the depth of the arc is measured with a feeler gage and a straightedge.

[B] It should be recognized that straightness is a perishable quality and may be altered by mishandling. The preservation of straightness in cold-finished bars requires the utmost care in subsequent handling. Specific straightness tolerances are sometimes required for carbon and alloy steels in which case the purchaser should inform the manufacturer of the straightness tolerances and the methods to be used in checking the straightness.

SPECIFICATION FOR CARBON STRUCTURAL STEEL 98

SA-36/SA-36M

(Identical with ASTM Specification A 36/A 36M-96) 98

1. Scope

1.1 This specification covers carbon steel shapes, plates, and bars of structural quality for use in riveted, bolted, or welded construction of bridges and buildings, and for general structural purposes.

1.2 Supplemental requirements are provided where improved internal quality and notch toughness are important. These shall apply only when specified by the purchaser in the order.

98 **1.3** When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized. See Appendix X3 of Specification A 6/A 6M for information on weldability.

1.4 The purchaser should consider specifying supplemental requirements, such as fine austenitic grain size and Charpy V-Notch Impact requirements, when Group 4 or Group 5 wide flange shapes are specified for use in other than column or compression applications.

1.5 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents, therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 *ASTM Standards:* 98

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

A 27/A 27M Specification for Steel Castings, Carbon, for General Application

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength

A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

A 325M Specification for High-Strength Bolts for Structural Steel Joints [Metric]

A 500 Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes

A 501 Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing

A 502 Specification for Steel Structural Rivets

A 563 Specification for Carbon and Alloy Steel Nuts

A 563M Specification for Carbon and Alloy Steel Nuts [Metric]

A 570/A 570M Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Quality

A 668 Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use

F 568 Specification for Carbon and Alloy Steel Externally Threaded Metric Fasteners

3. Appurtenant Materials

3.1 When components of a steel structure are identified with this ASTM designation but the product form is not listed in the scope of this specification, the material shall conform to one of the standards listed 98

in Table 1 unless otherwise specified by the purchaser. Table 1 does not provide any specification requirements to a manufacturer or processor. Orders to a manufacturer or processor should describe the required ASTM designation for product forms not listed in the scope of this specification. Unless otherwise specified, all plain and threaded bars used for anchorage purposes shall be subjected to mechanical tests and shall conform to the tensile requirements of Section 8; headed bolts used for anchorage purposes shall conform to Specification A 307 or F 568M; and all nuts shall conform to the requirements of Specification A 563, Grade A, or A 563M, Class 5.

4. General Requirements for Delivery

4.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

5. Bearing Plates

5.1 Unless otherwise specified, plates used as bearing plates for bridges shall be subjected to mechanical tests and shall conform to the tensile requirements of Section 8.

5.2 Unless otherwise specified, mechanical tests shall not be required for plates over 1½ in. [40 mm] in thickness used as bearing plates in structures other than bridges, subject to the requirement that they shall contain 0.20 to 0.33% carbon by heat analysis, that the chemical composition shall conform to the requirements of Table 2 in phosphorus and sulfur content, and that a sufficient discard shall be made to secure sound plates.

6. Process

6.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

6.2 No rimmed or capped steel shall be used for plates and bars over ½ in. [12.5 mm] thick or for shapes other than Group 1.

7. Chemical Requirements

7.1 The heat analysis shall conform to the requirements prescribed in Table 2, except as specified in 5.2.

7.2 The steel shall conform on product analysis to the requirements prescribed in Table 2, subject to the product analysis tolerances in Specification A 6/A 6M. **98**

7.3 When tension tests are waived in accordance with 8.2, chemistry consistent with the requirements in Table 2, and with the mechanical properties desired must be applied. **98**

8. Tensile Requirements

8.1 The material as represented by the test specimen, except as specified in 5.2 and 8.2, shall conform to the requirements as to the tensile properties prescribed in Table 3.

8.2 Shapes less than 1 in.^{2} [645 mm^2] in cross section and bars, other than flats, less than ½ in. [12.5 mm] in thickness or diameter need not be subjected to tension tests by the manufacturer.

9. Keywords

9.1 bars; bolted construction; bridges; buildings; carbon; plates; riveted construction; shapes; steel; structural steel; welded construction **98**

TABLE 1
APPURTENANT MATERIAL SPECIFICATIONS

98

NOTE — The specifier should be satisfied of the suitability of these materials for the intended application. Composition and/or mechanical properties may be different than specified in A 36/A 36M.

Material	ASTM Designation
Steel rivets	A 502, Grade 1
Bolts	A 307, Grade A or F 568M, Class 4.6
High-strength bolts	A 325 or A 325M
Steel nuts	A 563 or A 563M
Cast steel	A 27/A27M, Grade 65-35 [450-240]
Forgings (carbon steel)	A 668, Class D
Hot-rolled sheets and strip	A 570/A 570M, Grade 36
Cold-formed tubing	A 500, Grade 36
Hot-formed tubing	A 501

TABLE 2
CHEMICAL REQUIREMENTS

Note 1 — Where "..." appears in this table there is no requirement. The heat analysis for manganese shall be determined and reported as described in the heat analysis section of Specification A 6/A 6M.

Product	Shapes[A]	Plates[B]					Bars			
Thickness, in. [mm]	All	To ¾ [20], incl	Over ¾ to 1½ [20 to 40], incl	Over 1½ to 2½ [40 to 65], incl	Over 2½ to 4 [65 to 100], incl	Over 4 [100]	To ¾ [20], incl	Over ¾ to 1½ [20 to [40], incl	Over 1½ to 4 [100], incl	Over 4 [100]
Carbon, max, %	0.26	0.25	0.25	0.26	0.27	0.29	0.26	0.27	0.28	0.29
Manganese, %	...	...	0.80–1.20	0.80–1.20	0.85–1.20	0.85–1.20	...	0.60–0.90	0.60–0.90	0.60–0.90
Phosphorus, max, %	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur, max, %	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Silicon, %	0.40 max	0.40 max	0.40 max	0.15–0.40	0.15-0.40	0.15–0.40	0.40 max	0.40 max	0.40 max	0.40 max
Copper, min, % when copper steel is specified	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

[A] Manganese content of 0.85–1.35% and silicon content of 0.15–0.40% is required for shapes over 426 lb/ft [634 kg/m].

[B] For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to the maximum of 1.35%.

TABLE 3
TENSILE REQUIREMENTS[A]

Plates, Shapes,[B] and Bars:	
Tensile strength, ksi [MPa]	58–80 [400–500]
Yield point, min, ksi [MPa]	36 [250][C]
Plates and Bars[D,E]:	
Elongation in 8 in. [200 mm], min, %	20
Elongation in 2 in. [50 mm], min, %	23
Shapes:	
Elongation in 8 in. [200 mm], min, %	20
Elongation in 2 in. [50 mm], min, %	21[B]

[A] See Specimen Orientation under the Tension Tests section of Specification A 6/A 6M.

[B] For wide flange shapes over 426 lb/ft [634 kg/m], the 80 ksi [550 MPa] maximum tensile strength does not apply and a minimum elongation in 2 in. [50 mm] of 19%, applies.

[C] Yield point 32 ksi [220 MPa] for plates over 8 in. [200 mm] in thickness.

[D] Elongation not required to be determined for floor plate.

[E] For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See elongation requirement adjustments under the Tension Tests section of Specification A 6/A 6M.

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order. Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Those that are considered suitable for use with this specification are listed by title:

S5. Charpy V-Notch Impact Test.

S14. Bend Test.

ADDED SUPPLEMENTARY REQUIREMENTS

In addition, the following optional supplementary requirements are also suitable for use with this specification.

S91. Fine Austenitic Grain Size

S91.1 The steel shall be killed and have a fine austenitic grain size.

S97. Limitation on Rimmed or Capped Steel

S97.1 The steel shall be other than rimmed or capped.

SPECIFICATION FOR FERRITIC MALLEABLE IRON CASTINGS

SA-47

(Identical with ASTM Specification A 47-90)

1. Scope

1.1 This specification covers ferritic malleable castings for general engineering usage at temperatures from normal ambient to approximately 750°F.

1.2 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting and those of a test specimen cast from the same iron (see Appendix X1).

NOTE — A complete metric companion to Specification A 47 has been developed — A 47M; therefore, no metric equivalents are presented in this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings

A 644 Terminology Relating to Iron Castings

E 8 Test Methods of Tension Testing of Metallic Materials

E 10 Test Method for Brinell Hardness of Metallic Materials

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

E 140 Standard Hardness Conversion Tables for Metals (Relationship Between Brinell Hardness, Vickers Hardness, Rockwell Hardness, Rockwell Superficial Hardness, and Knoop Hardness)

2.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Domestic Shipment (Civilian Agencies)

3. Terminology

3.1 *Definitions* — Definitions for many terms common to iron are found in Terminology A 644.

4. Classification

4.1 Castings ordered and produced under this specification are classified under the following grades based on tests on separately cast test bars. Separately cast test bar shall be poured from the same lot of iron as the castings they represent and shall be heat treated with those castings except as provided in 7.2.3.

4.1.1 *Grade 32510*

4.1.1.1 The first three digits of the grade designation indicate the minimum yield strength (× 100 psi) and the last two digits indicate the minimum elongation (% in 2 in.).

5. Ordering Information

5.1 The purchase order for castings ordered under this specification shall state the specification designation, the year in which the specification was issued, and the grade of malleable iron to be supplied. Any option or special additions to the basic requirements of this specification shall be clearly and fully stipulated.

6. Chemical Composition

6.1 The chemical composition of the iron shall be such as to produce the structural and mechanical properties required by this specification.

7. Mechanical Properties

7.1 Factors influencing the properties of castings and their relationship to those of test specimens and separate test castings are discussed in Appendix X1.

7.2 *Tension Test Specimens:*

7.2.1 The tension test specimens shall be cast to the form and dimensions shown in Fig. 1or Fig. 2, in the same kind of molding material used for the production castings. At least three such specimens shall be cast from a representative ladle of iron either from each batch-melted heat or, in continuous melting, from each 4-h pour period during which the purchaser's castings were poured, or as otherwise agreed upon between manufacturer and purchaser.

7.2.2 All test specimens shall be suitably identified with the designation of either the batch-melted heat or the pour period of a continuous heat.

7.2.3 All test specimens shall be heat treated in the same production furnaces and in the same cycles as the castings they represent. However, in those instances wherein the critical sections of the production castings differ appreciably from that of the central portion of the test specimens, the time cycle for tempering the test specimens may be altered from that of the production lot in order to obtain similar microstructures or hardness, or both, in both specimen and castings. In such cases the hardness of the specimens shall be tested and reported along with the tensile test results.

7.2.4 The tension test is usually performed on unmachined specimens. However, for referee work the specimen may be machined from the standard cast bar to the dimensions shown in Fig. 3.

7.3 *Tension Test Method:*

7.3.1 The gage length of the standard tension specimen shall be 2.00 ± 0.01 in.

7.3.2 The diameter used to compute the cross-sectional area shall be the average between the largest and smallest diameters in that section of the 2 in. gage length having the smallest diameter and shall be measured to the nearest 0.001 in. No cast bar having a mean diameter less than 0.590 in. shall be accepted for test.

7.3.3 After reaching a stress equivalent to approximately half of the anticipated yield stress, the speed of the moving head of the testing machine shall not exceed 0.50 in./min through the breaking load.

7.3.4 While the values for yield point and yield strength are not identical, they are sufficiently close for most applications of ferritic malleable irons to be used interchangeably. They may be determined by any of the approved techniques described in the paragraphs on Determination of Yield Strength and Yield Point of Test Methods E 8. If determined as yield strength, that stress producing an extension under load of 0.01 in. over the 2 in. gage length (for example, 0.5% extension) or an offset of 0.2% shall be taken as the yield stress, which shall be converted to yield strength by dividing by the original cross-sectional area of the gage length found in accordance with 7.3.2. It shall be reported to the nearest 100 psi. In referee work, yield strength shall be determined as the stress which produces an extension under load of 0.5% of the gage length.

7.3.5 The tensile strength shall be the maximum load carried by the specimen during the test divided by the original cross-sectional area of the gage length, as found in accordance with 7.3.2. It shall be reported to the nearest 100 psi.

7.3.6 The elongation is the increase in gage length after fracture of a tensile specimen, measured to the nearest 0.01 in., expressed as a percentage of the original gage length. It shall be reported to the nearest 0.5%.

7.4 *Retesting:*

7.4.1 If, after testing, a specimen shows evidence of a defect, another tension test may be made on a companion specimen. Also, a retest shall be permitted whenever fracture occurs outside the central 50% of the gage length.

7.4.2 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification, the castings represented by these test specimens shall be rejected. A valid test is one wherein the test specimen has been properly prepared and appears to be sound and on which the approved test procedure has been followed.

7.4.3 If sufficient companion test bars are unavailable, the manufacturer shall have the option of testing a specimen cut from a representative casting. Therefore, as stated in 1.3, the mechanical properties of such tension test specimen removed from a production casting

will not necessarily correspond to those of a standard separately cast test specimen, the values in Table 1 do not apply. Instead, the mechanical properties of the test specimen from the casting musts equal or exceed the average of those from similar test specimens removed from the same location from two castings of the same design where separately cast test bars meet the requirements of Table 1.

7.4.4 If the first test results indicate that a reheat treatment is needed to meet the test requirements, the entire lot of castings and the representative test specimens shall be reheat treated together. Testing shall then be repeated in accordance with 7.4.1 through 7.4.3.

7.4.5 The result of all tests, including retests, shall be posted in permanent records, which shall state any abnormalities observed during the test and in the fractured ends. Such records shall be kept for at least 1 year after shipment of the production castings and shall be available for examination by the purchaser or by his authorized representative.

7.4.6 If not covered in the purchase agreement, the frequency of tension testing shall be in accordance with 7.2.1 and sufficiently often to assure uniformity of product and compliance with minimum test requirements.

7.4.7 Tension test results, obtained in accordance with the above subsections, must conform to the values of Table 1 for acceptance under this specification except as provided in 7.4.3.

7.4.8 When agreed upon between manufacturer and purchaser, tested specimens or unbroken test bars shall be preserved by the manufacturer for a period of three months after the date of the test report.

7.5 *Hardness Test* — If the purchase agreement requires hardness testing, the acceptable hardness range shall be stated and a test location clearly shown on the covering drawing(s).

7.5.1 *Hardness Test Method* — The Brinell method of hardness testing in accordance with Test Method E 10 shall be employed whenever possible.

7.5.2 For castings of such size or shape that do not permit Brinell testing with the standard 3000-kgf load, the 500 kgf may be employed, the hardness number being reported as HB 10/500/15. In very unusual cases where it is impossible to use the Brinell method, the Rockwell test may be substituted, using Test Methods E 18 with an appropriate Rockwell scale. Conversions of hardness values from one method to another according to Standard E 140, which does not specifically cover cast irons, are approximate only and, therefore, are generally inadvisable.

7.5.3 Sufficient material shall be removed from the cast surface to ensure that the measured surface is representative.

7.5.4 Sampling procedures and the frequency of hardness testing shall be fully detailed on the purchase agreement. Otherwise, hardness tests shall be performed at the discretion of the producer.

7.5.5 Castings failing to conform to the required hardness range may be reheat treated and retested. If after reheat treating they still fail the hardness requirements, they shall be rejected.

7.5.6 Typical hardness maximums for this grade of malleable iron are listed in Table 2.

8. Microstructure Requirements

8.1 The microstructure of the malleable iron shall consist of temper carbon nodules distributed through a ferritic matrix and shall be free of excessive pearlite, massive carbides, and primary graphite.

8.2 When agreed upon by the purchaser and producer, the maximum decarburization at any as-cast-surface after heat treatment may be stipulated in writing as measured by visual depletion of combined carbon after polishing, etching in nital, and viewing at 100×.

8.3 In reference work, the metallographic practice recommended in Test Method A 247 shall be followed.

9. Soundness Requirements

9.1 All castings, on visual examination, shall be sound and free of obvious shrinkage and porosity.

9.2 If the purchaser requires soundness tests to be performed, it shall be so stated in the purchase agreement, and the method and soundness requirements shall be detailed.

10. Dimensional Requirements

10.1 The casting shall conform to the dimensions given on drawings furnished by the purchaser, or to the dimensions established by the pattern equipment supplied by the purchaser, or as agreed upon in specific cases to gages supplied by the purchaser. Variation in any solid dimensions will be permitted as shown in

Table 3, unless otherwise agreed upon by the foundry and purchaser.

11. Workmanship, Finish, and Appearance

11.1 The surface of the casting shall be inspected visually, particularly in critical areas, for such surface defects as cracks, hot tears, adhering sand and scale, cold shuts, and gas holes.

11.2 No repairing, plugging, or welding of any kind shall be permitted unless written permission is granted by the purchaser.

11.3 Castings that have been repaired by welding shall be reannealed so that their microstructure will comply with Section 8.

12. Responsibility for Inspection

12.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspections required by this specification, using his own or other reliable facilities, and he shall maintain complete records of all such tests and inspections. Such records shall be available for review by the purchaser.

12.2 The purchaser reserves the right to perform any inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to the prescribed requirements.

13. Rejection and Rehearing

13.1 Any casting or lot of castings failing to comply with the requirements of this specification may, where possible, be reprocessed, retested, and reinspected. If the tests and inspections on the reprocessed casting(s) shown compliance with this specification, the castings shall be acceptable; if they do not, they shall be rejected.

13.2 If the purchaser should find that a casting or lot of castings fails to comply with this specification subsequent to receipt at his facility, he shall so notify the manufacturer promptly and in no case later than six weeks after receipt of the shipment, stating clearly his basis for rejection. In case of dissatisfaction with the purchaser's claim, the manufacturer may apply for a hearing before final rejection of the shipment.

14. Certification

14.1 When specified by the purchaser's order or contract, a manufacturer's certification or compliance statement that the casting or lot of castings was made, sampled, tested, and inspected in accordance with this specification, including a report of test results signed by an authorized agent of the manufacturer, shall be furnished at the time of shipment, and such certification or compliance statement shall be the basis for acceptance of the casting or lot of castings.

15. Product Marking

15.1 When the size of the casting permits, each casting shall bear the identifying mark of the manufacturer and the part or pattern number at a location shown on the covering drawing and, if not shown on the drawing, at such a location at the discretion of the producer that the identification will not interfere with subsequent processing and service of the casting.

16. Packaging and Package Marking

16.1 Unless otherwise stated in the contract or order, the cleaning, preservation, and packing of castings for shipment shall be in accordance with the manufacturer's commercial practice. Packaging and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

16.2 *U.S. Government Procurement* — When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 and MIL-STD-129.

TABLE 1
TENSION TEST REQUIREMENTS

Grade	Tensile Strength, min, psi	Yield Strength, min, psi	Elongation in 2 in., min, %
32510	50 000	32 500	10

TABLE 2
TYPICAL HARDNESS

Grade	Hardness, maximum HB	Indentation Value Diameters, mm
32510	156	4.8

TABLE 3
PERMISSIBLE VARIATION IN ANY SOLID DIMENSION

Size, in.	Tolerance, ± in.
Up to 1	0.03
1 to 6	0.06
6 to 12	0.12
12 to 18	0.15
18 to 24	0.19
24 to 36	0.22

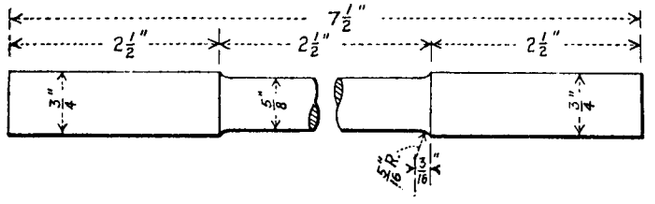
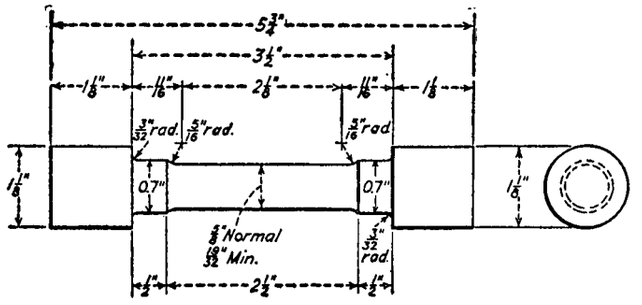
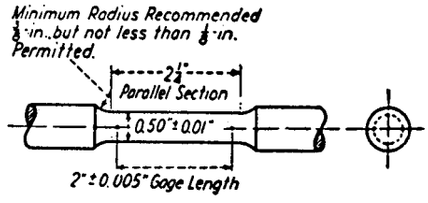


FIG. 1 TENSION TEST SPECIMEN



NOTE: — Modifications may be made in the dimensions indicated above for those details of the specimen outside of the gage length as required by testing procedure and equipment.

FIG. 2 ALTERNATIVE UNMACHINED TENSION TEST SPECIMEN



NOTE — The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. larger in diameter than the center.

FIG. 3 MACHINED TENSION TEST SPECIMEN

SUPPLEMENTARY REQUIREMENTS

S1. Special Conditions

S1.1 If agreed upon in writing by the foundry and purchaser, the malleable iron castings may be required to meet special conditions as to soundness, hardness or other property, dimensions, surface quality, or a combination of conditions.

S2. Test Lugs

S2.1 If requested in writing or if included on the pattern(s) or pattern drawing(s), test lugs may be cast on all castings of sufficient size to permit their incorporation. The size of such lugs shall be proportional to the thickness of the casting. On castings over 24 in. in length, a test lug shall be cast near each end such as not to interfere with any subsequent processing of the castings. The purchase order shall stipulate whether the foundry's inspector or the purchaser's inspector shall break, inspect, and pass judgment on the fracture quality of these test lugs.

S3. Destructive Tests

S3.1 At the option of the purchaser or his representative, a casting of each design ordered may be tested to destruction, or otherwise broken up, to determine the presence of any manufacturing condition which might be detrimental to the serviceability of the casting.

S4. Special Tension Specimens

S4.1 If tension specimens are to be machined from castings, their location in the casting, the specimen dimensions, and the required properties shall be agreed upon in writing by the foundry and purchaser.

S5. Zinc-Coated Castings

S5.1 When specified in the contract or purchase order, castings shall be zinc-coated by the hot-dip process in accordance with Specification A 153. Castings shall be of a composition that will preclude the possibility of galvanizing embrittlement, or shall be either cooled from the anneal or subsequently heat treated so as to be immunized against such embrittlement. If regalvanizing is required, procedures for regalvanizing castings and determining the effect on the casting performance must be by agreement between the purchaser and the seller.

S6. Marking of Casting for Government Procurement

S6.1 When castings are specified for government procurement, the location of the permanent markings specified in 15.1, as well as any special marking for mechanical or physical properties (either permanent or temporary), shall be as indicated on the government drawings or sketches.

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of malleable iron castings are influenced by a number of factors, which include the cooling rate during solidification, chemical composition, the heat treatment, the design of the casting, section thickness, and the location and effectiveness of gates, risers, and chills.

X1.2 Because of the complexity of these factors in influencing the properties of the final product, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be determined by appropriate experimentation.

X1.3 The specimen specified in 7.2.1 as the standard tensile test bar for malleable iron has a $\frac{5}{8}$ in. diameter test section that reasonably represents a typical section of the general run of malleable iron castings. Furthermore, the initial freezing of malleable irons as homogeneous white iron, together with the heat treatment which is inherent in the manufacture of malleable iron, tends to reduce the section-sensitivity effect. Therefore, where experimentation into precise properties within a given casting would be unfeasible, this standard test bar, made like any typical casting, should provide a practical approximation of the properties that can be expected in average sound malleable iron casting.

X1.4 If malleable iron castings are welded, the microstructure of the iron is markedly affected, particularly in the heat-affected zone. Therefore, since this may adversely affect the properties of the casting, the welding of malleable iron castings should be done under strict metallurgical control, followed by appropriate post-weld heat treatment, to minimize the substantial reductions in ductility, impact resistance, and machinability that could result, particularly in the vicinity of the weldment. Nevertheless, it is generally considered inadvisable to join castings to similar castings or to other materials, by fusion welding out in the field, or in manufactured assemblies, without fully testing the entire completed part.

SPECIFICATION FOR PIPE, STEEL, BLACK AND HOT-DIPPED, ZINC-COATED, WELDED AND SEAMLESS

SA-53

(Identical to ASTM Specification A 53-96) 98

1. Scope

1.1 This specification covers seamless and welded black and hot-dipped galvanized steel pipe in NPS $\frac{1}{8}$ to 26 (Note 1), inclusive, with nominal (average) wall thickness as given in Tables X2.2 and X2.3. Pipe having other dimensions (Note 2) may be furnished provided such pipe complies with all other requirements of this specification.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

NOTE 2 — A comprehensive listing of standardized pipe dimensions is contained in American National Standard ANSI B36.10.

1.2 Pipe may be furnished in the following types and grades:

98 **1.2.1** *Type F* — Furnace-butt welded, continuous welded Grade A,

1.2.2 *Type E* — Electric-resistance welded, Grades A and B, and

1.2.3 *Type S* — Seamless, Grades A and B.

NOTE 3 — See Appendix X1 for definitions of types of pipe.

1.3 Pipe ordered under this specification is intended for mechanical and pressure applications and is also acceptable for ordinary uses in steam, water, gas, and air lines. It is suitable for welding, and suitable for forming operations involving coiling, bending, and flanging, subject to the following qualifications:

1.3.1 Type F is not intended for flanging.

1.3.2 When Types S and E are required for close coiling or cold bending, Grade A should be specified. This provision is not intended to prohibit the cold bending of Grade B pipe.

1.3.3 When pipe is required for close coiling, this should be specified on the order.

1.3.4 Type E may be furnished either nonexpanded or cold expanded at the option of the manufacturer. When pipe is cold expanded, the amount of expansion shall not exceed $1\frac{1}{2}$% of the outside diameter pipe size.

1.4 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents may be approximate.

1.5 The following precautionary caveat pertains only 98 to the test method portion, Sections 9, 10, 11, 12, 13, and 14, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* 98

A 90 Test Method for Weight (Mass) of Coating on Iron or Steel Articles with Zinc or Zinc-Alloy Coatings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 865 Specification for Threaded Couplings, Steel, Black and Zinc-Coated (Galvanized) Welded or Seamless, for Use in Steel Pipe Joints
B 6 Specification for Zinc
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 59 Method for Sampling Steel and Iron for Determination of Chemical Composition
E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation
E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

98 **2.2** *ANSI Standards:*
ASC X12
B1.20.1 Pipe Threads, General Purpose
B36.10 Welded and Seamless Wrought Steel Pipe

2.3 *Military Standards:*
MIL-STD-129 Marking for Shipment and Storage
MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage

2.4 *Federal Standards:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.5 *API Standard:*
5L Specification for Line Pipe

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Specification designation,

3.1.2 Quantity (feet, meters, or number of lengths),

98 **3.1.3** Grade (see Table 1),

98 **3.1.4** Type (see 1.2 and Table 2),

3.1.5 Finish (black or galvanized),

3.1.6 Size (either nominal (NPS) and weight class or schedule number, or both; or outside diameter, and nominal wall thickness, Tables X2.2 and X2.3),

3.1.7 Length (specific or random, Section 17),

3.1.8 End finish (plain end or threaded, Section 18),

3.1.8.1 Threaded and coupled,

3.1.8.2 Threads only (no couplings), if desired,

3.1.8.3 Plain end, if desired,

3.1.8.4 Couplings power tight, if desired,

3.1.8.5 Taper tapped couplings for NPS 2 and smaller, if desired,

3.1.9 Close coiling, if required (see 1.3.3),

3.1.10 Skelp for tension tests, if permitted (see 12.2),

3.1.11 Certification (see Section 23),

3.1.12 End use of material,

3.1.13 Special requirements, and

3.1.14 Selection of applicable level of preservation and packaging and level of packing required, if other than as specified or if MIL-STD-163 applies (see 22.2).

4. Materials and Manufacture

4.1 The steel for both seamless and welded pipe shall be made by one or more of the following processes: open-hearth, electric-furnace, or basic-oxygen.

4.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 The weld seam of electric-resistance welded pipe in Grade B shall be heat treated after welding to a minimum of 1000°F (540°C) so that no untempered martensite remains, or otherwise processed in such a manner that no untempered martensite remains.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition in Table 1 and the chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751. 98

6. Product Analysis

98 **6.1** An analysis of two pipes from each lot of 500 lengths, or fraction thereof, may be made by the purchaser. Samples for chemical analysis, except for spectrographic analysis, shall be taken in accordance with Method E 59. The chemical composition thus determined shall conform to the requirements specified in Table 1.

6.2 If the analysis of either pipe does not conform to the requirements specified in Table 1, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified.

7. Tensile Requirements

98 **7.1** The material shall conform to the requirements as to tensile properties prescribed in Table 2.

7.2 The yield strength corresponding to a permanent offset of 0.2% of the gage length of the specimen or to a total extension of 0.5% of the gage length under load shall be determined.

7.3 The test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe ordered. This test will not be required for pipe under NPS 8.

7.4 Transverse tension test specimens for electric-welded pipe NPS 8 and larger shall be taken opposite the weld. All transverse test specimens shall be approximately 1½ in. (38.1 mm) wide in the gage length, and shall represent the full wall thickness of the pipe from which the specimen was cut. This test is required for NPS 8 and larger.

8. Bending Requirements

8.1 For pipe NPS 2 and under, a sufficient length of pipe shall be capable of being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the outside diameter of the pipe, without developing cracks at any portion and without opening the weld.

8.2 When ordered for close coiling, the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the outside diameter of the pipe, without failure.

8.3 Double-extra-strong pipe over NPS 1¼ need not be subjected to the bend test.

9. Flattening Test

9.1 The flattening test shall be made on pipe over NPS 2 with all thicknesses extra strong and lighter.

9.2 *Seamless Pipe:*

9.2.1 For seamless pipe, a section not less than 98
2½ in. (63.5 mm) in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside, outside, or end surfaces, except as provided for in 9.7, shall occur until the distance between the plates (Table 3) is less than the value of H calculated as follows:

$$H = (1 + e)t/(e + t/D)$$

where:

H = distance between flattening plates, in. (Note 4),
e = deformation per unit length (constant for a given grade of steel, 0.09 for Grade A, and 0.07 for Grade B),
t = specified wall thickness, in., and
D = specified outside diameter, in.

9.2.2 During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material that is revealed during the entire flattening test shall be cause for rejection.

NOTE 4 — The H values have been calculated for standard and extra-heavy weight sizes from NPS 2½ to 24, inclusive, and are shown in Table X2.1.

9.3 *Electric-Resistance-Welded Pipe* — A specimen at least 4 in. (101.6 mm) in length shall be flattened cold between parallel plates in three steps with the weld located either 0° or 90° from the line of direction of force as required in 9.3.1. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than two thirds of the original outside diameter of the pipe. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces, except as provided for in 9.7, shall occur until the distance between the plates is less than one third of the original outside diameter of the pipe but is not less than five times the wall thickness of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe

meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

9.3.1 For pipe produced in single lengths, the flattening test specified in 9.3 shall be made on both crop ends cut from each length of pipe. The tests from each end shall be made alternately with the weld at 0° and at 90° from the line of direction of force. For pipe produced in multiple lengths, the flattening test shall be made on crop ends representing the front and back of each coil with the weld at 90° from the line of direction of force, and on two intermediate rings representing each coil with the weld 0° from the line of direction of force.

9.4 *Continuous-Welded Pipe* — For continuous-welded pipe, a specimen not less than 4 in. in length shall be flattened cold between parallel plates in three steps. The weld shall be located 90° from the line of direction of force. During the first step, which is a test for quality of the weld, no cracks or breaks on the inside, outside, or end surfaces shall occur until the distance between the plates is less than three fourths of the original outside diameter for butt-welded pipe. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside, outside, or end surfaces, except as provided for in 9.7, shall occur until the distance between the plates is less than 60% of the original outside diameter for continuous-welded pipe. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

9.5 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 20.

9.6 Superficial ruptures as a result of surface imperfections shall not be cause for rejection.

9.7 When low *D*-to-*t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than 10.

10. Hydrostatic Test

10.1 The hydrostatic test shall be applied, without leakage through the pipe wall, to each length of pipe except as provided for in 11.2 for seamless pipe. **98**

10.2 Each length of plain-end pipe shall be tested by the manufacturer to the hydrostatic pressures prescribed in Table X2.2, and each threaded-and-coupled length shall be hydrostatically tested to pressures prescribed in Table X2.3. The hydrostatic test may be applied, at the discretion of the manufacturer, on pipe with plain ends, with threads only, or with threads and couplings and may be applied to pipe in single lengths or multiple lengths.

NOTE 5 — The hydrostatic test pressures given herein are inspection test pressures, are not intended as a basis for design, and do not have any direct relationship to working pressures. **98**

10.3 The minimum hydrostatic test pressure required to satisfy these requirements need not exceed 2500 psi (17.2 MPa) for NPS 3 and under, nor 2800 psi (19.3 MPa) for all sized over NPS 3. This does not prohibit testing at a higher pressure at the manufacturer's option. The hydrostatic pressure shall be maintained for not less than 5 s for all sizes of seamless and electric-welded pipe.

11. Nondestructive Electric Test

11.1 *Type E Pipe:*

11.1.1 The weld seam of each length of ERW pipe NPS 2 and larger shall be tested with a nondestructive electric test as follows:

11.1.2 *Ultrasonic and Electromagnetic Inspection* — Any equipment utilizing the ultrasonic or electromagnetic principles and capable of continuous and uninterrupted inspection of the weld seam shall be used. The equipment shall be checked with an applicable reference standard as described in 11.1.3 at least once every working turn or not more than 8 h to demonstrate its effectiveness and the inspection procedures. The equipment shall be adjusted to produce well-defined indications when the reference standard is scanned by the inspection unit in a manner simulating the inspection of the product.

11.1.3 *Reference Standards* — Reference standards shall have the same specified diameter and thickness as the product being inspected, and may be of any convenient length as determined by the pipe manufacturer. Reference standards shall contain machined notches, one on the inside surface and one on the

outside surface, or a drilled hole, as shown in Fig. 1, at the option of the pipe manufacturer. The notches shall be parallel to the weld seam, and shall be separated by a distance sufficient to produce two separate and distinguishable signals. The $\frac{1}{8}$ in. (3.2 mm) hole shall be drilled through the wall and perpendicular to the surface of the reference standard as shown in Fig. 1. Care shall be taken in the preparation of the reference standard to ensure freedom from fins or other edge roughness, or distortion of the pipe.

98 NOTE 6 — The reference standards defined in 11.1.3 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size-imperfection detectable by such equipment.

98 **11.1.4** *Acceptance Limits* — Table 4 gives the height of acceptance limit signals in percent of the height of signals produced by reference standards. Imperfections in the weld seam that produce a signal greater than the acceptance limit signal given in Table 5 shall be considered an injurious defect unless the pipe manufacturer can demonstrate that the imperfection does not reduce the effective wall thickness beyond $12\frac{1}{2}$% of the specified wall thickness.

11.2 *Seamless Pipe* — As an alternative to the hydrostatic test, and when specified by the purchaser, the full body of each seamless pipe shall be tested with a nondestructive electric test in accordance with Practices E 213, E 309, or E 570. In this case each length so furnished shall include the mandatory marking of the letters "NDE." Except as provided in 11.2.6.2 it is the intent of this test to reject pipe with imperfections which produce test signals equal to or greater than that of the calibration standard.

11.2.1 When the nondestructive electric test is performed, the lengths shall be marked with the letters "NDE." The certification, when required, shall state Nondestructive Electric Tested and shall indicate which of the tests was applied. Also, the letters NDE shall be appended to the product specification number and material grade shown on the certification.

11.2.2 The following information is intended to facilitate the use of this specification.

11.2.2.1 The reference standards defined in 11.2.3 through 11.2.5 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

11.2.2.2 The ultrasonic testing can be performed to detect both longitudinal and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep defects.

11.2.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type.

11.2.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. The provisions of this specification only require longitudinal calibration for flux leakage. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

11.2.2.5 The hydrostatic test referred to in 10.2 has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall defects or defects that extend an appreciable distance into the wall without complete penetration.

11.2.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

11.2.3 For ultrasonic testing, the calibration reference notches shall be at the option of the producer, and shall be any one of the three common notch shapes shown in Practice E 213. The depth of notch shall not exceed 12.5% of the specified wall thickness of the pipe or 0.004 in., whichever is greater.

11.2.4 For eddy current testing, the calibration pipe shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection.

11.2.4.1 *Drilled Hole* — Depending upon the pipe diameter the calibration pipe shall contain three holes spaced 120° apart or four holes spaced 90° apart and sufficiently separated longitudinally to ensure separately distinguishable responses. The holes shall be drilled radially and completely through the pipe wall, care being taken to avoid distortion of the pipe while

drilling. Depending upon the pipe diameter the calibration pipe shall contain the following hole:

NPS	Diameter of Drilled Hole
≤ ½ in.	0.039 in. (1 mm)
> ½ ≤ 1¼ in.	0.055 in. (1.4 mm)
> 1¼ ≤ 2 in.	0.071 in. (1.8 mm)
> 2 ≤ 5 in.	0.087 in. (2.2 mm)
> 5 in.	0.106 in. (2.7 mm)

11.2.4.2 *Transverse Tangential Notch* — Using a round tool or file with a ¼ in. (6.4 mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. The notch shall have a depth not exceeding 12.5% of the specified wall thickness of the pipe or 0.012 in. (0.3 mm), whichever is greater.

11.2.4.3 *Longitudinal Notch* — A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12.5% of the specified wall thickness of the tube or 0.012 in., whichever is greater. The length of the notch shall be compatible with the testing method.

11.2.4.4 *Compatibility* — The discontinuity in the calibration pipe shall be compatible with the testing equipment and the method being used.

11.2.5 For flux leakage testing, the longitudinal calibration reference notches shall be straight sided notches machined in a radial plane parallel to the pipe axis. For wall thickness under 0.5 in., outside and inside notches shall be used. For wall thickness equal and above 0.5 in. only an outside notch shall be used. Notch depth shall not exceed 12.5% of the specified wall thickness, or 0.012 in., whichever is greater. Notch length shall not exceed 1 in., and the width shall not exceed the depth. Outside diameter and inside diameter notches shall be located sufficiently apart to allow separation and identification of the signals.

11.2.6 Pipe producing a signal equal to or greater than the signal produced by the calibration standard shall be subject to rejection. The area producing the signal may be reexamined.

11.2.6.1 Test signals produced by imperfections that cannot be identified, or produced by cracks or crack-like imperfections, shall result in rejection of the pipe, unless it is repaired and retested. To be accepted, the pipe must pass the same specification test to which it was originally subjected, provided that the remaining wall thickness is not decreased below that permitted by the specification. The O.D. at the point of grinding may be reduced by the amount as removed.

11.2.6.2 Test signals produced by visual imperfections may be evaluated in accordance with the provision of Section 20. A few examples of these imperfections would be straightener marks, cutting chips, scratches, steel die stamps, stop marks, or pipe reducer ripple.

11.2.7 The test methods described in this section may not be applicable for inspecting the end portion of pipes. This condition is referred to as end effect. The length of the end effect shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

12. Number of Tests

12.1 Except as required by 12.3, for seamless and electric-resistance-welded pipe, one of each of the applicable tests specified in Section 7, 8.2, and Section 9 shall be made on one length of pipe from each lot of 500 lengths, or fraction thereof, of each size. A length is defined as the length as ordered, except that in the case of orders for cut lengths shorter than single random, the term lot shall apply to the lengths as rolled, prior to cutting to the required short lengths.

12.2 For continuous-welded pipe, one of each of the tests specified in Sections 7 and 9 and 8.2 shall be made on one length of pipe from each lot of 25 tons, or fraction thereof, of pipe 1½ in. and smaller, and from each lot of 50 tons, or fraction thereof, of pipe NPS 2 and larger.

12.3 The number of flattening tests for electric-resistance-welded pipe shall be in accordance with 9.3.1.

12.4 Each length of pipe shall be subjected to the hydrostatic test specified in Section 10.

13. Retests

13.1 If the results of the mechanical tests of any lot do not conform to the requirements specified in Sections 7, 8, and 9, retests may be made on additional pipe of double the original number from the same lot, each of which shall conform to the requirements specified.

13.2 If any section of the pipe fails to comply with the requirements of 9.3 for pipe produced in single lengths, other sections may be cut from the same end

of the same length until satisfactory tests are obtained, except that the finished pipe shall not be shorter than 80% of its length after the original cropping; otherwise the length shall be rejected. For pipe produced in multiple lengths, retests may be cut from each end of each individual length in the multiple. Such tests shall be made with the weld alternately 0° and 90° from the line of direction of force.

14. Test Methods

14.1 The test specimens and the tests required by this specification shall conform to those described in the latest issue of Test Methods and Definitions A 370.

14.2 The longitudinal tension test specimen shall be taken from the end of the pipe or, for continuous-welded pipe, may be taken from the skelp, at a point approximately 90° from the weld, and shall not be flattened between gage marks. The sides of each specimen shall be parallel between gage marks. If desired, the tension tests may be made on the full section of pipe. When impracticable to pull a test specimen in full thickness, the standard 2 in. (50.8 mm) gage length tension test specimen shown in Fig. 19 of Test Methods and Definitions A 370 may be used.

14.3 Transverse weld test specimens from electric-resistance-welded pipe shall be taken with the weld at the center of the specimen. All transverse test specimens shall be approximately 1½ in. (38.1 mm) wide in the gage length and shall represent the full wall thickness of the pipe from which the specimen was cut.

14.4 Test specimens for the bend and flattening tests consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends taken with welded pipe.

14.5 All specimens shall be tested at room temperature.

15. Dimensions and Weights

15.1 The dimensions and weights of plain-end pipe included in this specification are listed in Table X2.2. Dimensions and weights of threaded-and-coupled pipe are listed in Table X2.3.

15.2 The dimensions and weights furnished under this specification are included in ANSI B36.10.

16. Permissible Variations in Weight and Dimensions

16.1 *Weight* — The weight of the pipe as specified in Tables X2.2 and X2.3 shall not vary by more than ±10%.

NOTE 7 — The weight tolerance is determined from the weights of the customary lifts of pipe as produced for shipment by the mill, divided by the number of feet of pipe in the lift. On pipe sizes over NPS 4, where individual lengths may be weighed, the weight tolerance is applicable to the individual length. 98

16.2 *Diameter* — For pipe NPS 1½ and under, the outside diameter at any point shall not vary more than $\pm 1/64$ in. (0.40 mm) from the standard specified. For pipe NPS 2 and over, the outside diameter shall not vary more than ±1% from the standard specified.

16.3 *Thickness* — The minimum wall thickness at any point shall be not more than 12.5% under the nominal wall thickness specified. The minimum wall thickness on inspection shall conform to the requirements in Table X2.4.

17. Lengths

17.1 Unless otherwise specified, pipe lengths shall be in accordance with the following regular practice.

17.1.1 Pipe of weights lighter than extra strong shall be in single-random lengths of 16 to 22 ft (4.88 to 6.71 m), but not more than 5% of the total number of threaded lengths may be jointers (two pieces coupled together). When ordered with plain ends, 5% may be in lengths of 12 to 16 ft (3.66 to 4.88 m).

17.1.2 Pipe of extra-strong and heavier weights shall be in random lengths of 12 to 22 ft (3.66 to 6.71 m). Five percent may be in lengths of 6 to 12 ft (1.83 to 3.66 m).

17.1.3 When extra-strong or lighter pipe is ordered in double-random lengths, the minimum lengths shall be not less than 22 ft (6.71 m), with a minimum average for the order of 35 ft (10.67 m).

17.1.4 When lengths longer than single random are required for wall thicknesses heavier than extra-strong, the length shall be subject to negotiation.

17.1.5 When pipe is furnished with threads and couplings, the length shall be measured to the outer face of the coupling.

18. End Finish

18.1 When ordered with plain ends, the pipe shall be furnished to the following practice, unless otherwise specified.

18.1.1 NPS $1\frac{1}{2}$ and Smaller — Unless otherwise specified on the purchase order, end finish shall be at the option of the manufacturer.

18.1.2 NPS 2 and Larger:

18.1.2.1 Pipe of standard or extra strong weights, or in wall thickness less than 0.500 in. (12.7 mm), other than double extra strong pipe, shall be plain-end beveled with ends beveled to an angle of 30°, +5°, −0°, measured from a line drawn perpendicular to the axis of the pipe, and with a root face of $\frac{1}{16}$ in. ± $\frac{1}{32}$ in. (1.6 mm ± 0.79 mm).

18.1.2.2 Pipe with wall thicknesses over 0.500 in. (12.7 mm), and all double extra strong, shall be plain-end square cut.

18.2 When ordered with threaded ends, the pipe ends shall be provided with a thread in accordance with the gaging practice and tolerances of ANSI B1.20.1. For standard-weight pipe in sizes 6 in. and smaller, refer to Table X3.1 for threading data. For standard-weight pipe 8 in. and larger and all sizes of extra-strong weight and double extra-strong weight, refer to Table X3.2 for threading data. Threaded pipe sizes 4 in. and larger shall have thread protectors on the ends not protected by a coupling.

18.3 When ordered with couplings, one end of each length of pipe shall be provided with a coupling manufactured in accordance with Specification A 865. The coupling threads shall be in accordance with the gaging practice of ANSI B1.20.1. The coupling shall be applied handling-tight, unless power-tight is specified on the order. Couplings are to be made of steel. Taper-tapped couplings shall be furnished on all weights of threaded pipe $2\frac{1}{2}$ in. and larger. For sizes 2 in. and smaller, it is regular practice to furnish straight-tapped couplings for standard-weight pipe and taper-tapped couplings for extra-strong and double extra-strong pipe. If taper-tapped couplings are required for sizes 2 in. and under on standard-weight pipe, line pipe in accordance with API Specification 5L should be ordered. The taper-tapped couplings provided on line pipe in these sizes may be used on mill-threaded standard-weight pipe of the same size.

19. Galvanized Pipe

19.1 Galvanized pipe ordered under this specification shall be coated with zinc inside and outside by the hot-dip process. The zinc used for the coating shall be any grade of zinc conforming to Specification B 6.

19.2 *Weight of Coating* — The weight of zinc coating shall be not less than 1.8 oz/ft^2 (0.55 kg/m^2) as determined from the average results of the two specimens taken for test in the manner prescribed in 19.5 and not less than 1.6 oz/ft^2 (0.49 kg/m^2) for either of these specimens. The weight of coating expressed in ounces per square foot shall be calculated by dividing the total weight of zinc, inside plus outside, by the total area, inside plus outside, of the surface coated. Each specimen shall have not less than 1.3 oz/ft^2 (0.40 kg/m^2) of zinc coating on each surface, calculated by dividing the total weight of zinc on the given surface (outside or inside) by the area of the surface coated (outside or inside).

19.3 *Weight of Coating Test* — The weight of zinc coating shall be determined by a stripping test in accordance with Test Method A 90. The total zinc on each specimen shall be determined in a single stripping operation.

19.4 *Test Specimens* — Test specimens for determination of weight of coating shall be cut approximately 4 in. (101.6 mm) in length.

19.5 *Number of Tests* — Two test specimens for the determination of weight of coating shall be taken, one from each end of one length of galvanized pipe selected at random from each lot of 500 lengths or fraction thereof, of each size.

19.6 *Retests* — If the weight of coating of any lot does not conform to the requirements specified in 19.2, retests of two additional pipes from the same lot shall be made, each of which shall conform to the requirements specified.

19.7 When pipe ordered under this specification is to be galvanized, the tension, flattening, and bend tests shall be made on the base material before galvanizing. When specified, results of the mechanical tests on the base material shall be reported to the purchaser. If impracticable to make the mechanical tests on the base material before galvanizing, such tests may be made on galvanized samples, and any flaking or cracking of the zinc coating shall not be considered cause for rejection. When galvanized pipe is bent or otherwise fabricated to a degree which causes the zinc coating

to stretch or compress beyond the limit of elasticity, some flaking of the coating may occur.

20. Workmanship, Finish and Appearance

20.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required, but may be necessary to ensure compliance with 20.2.

20.2 Surface imperfections that penetrate more than 12½% of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with defects shall be given one of the following dispositions:

20.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits,

20.2.2 Type S pipe and the parent metal of Type E pipe, except within ½ in. (12.7 mm) of the fusion line of the electric resistance seam, may be repaired in accordance with the welding provisions of 20.5. Repair welding of Type F pipe and the weld seam of Type E is prohibited.

20.2.3 The section of pipe containing the defect may be cut off within the limits of requirement on length, or

20.2.4 Rejected.

20.3 At the purchaser's discretion, pipe shall be subjected to rejection if surface defects repaired in accordance with 20.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

20.4 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

20.4.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In the case of a dispute, the measurement determined by use of the mechanical caliper shall govern.

20.5 Weld repair shall be permitted only subject to approval of the purchaser and in accordance with Specification A 530/A 530M.

20.6 The finished pipe shall be reasonably straight.

20.7 The pipe shall contain no dents greater than 10% of the pipe diameter or ¼ in., whichever is smaller, measured as a gap between the lowest point of the dent and a prolongation of the original contour of the pipe. Cold-formed dents deeper than ⅛ in. shall be free of sharp bottom gouges; the gouges may be removed by grinding provided the remaining wall thickness is within specified limits. The length of the dent in any direction shall not exceed one half the pipe diameter.

21. Inspection

21.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

22. Rejection

22.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

22.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

23. Certification

98 **23.1** The producer or supplier shall, upon request, furnish to the purchaser a certificate of inspection stating that the material has been manufactured, sampled, tested, and inspected in accordance with this specification, and has been found to meet the requirements.

98 **23.2** *Report* — For Types E and S, the producer or supplier shall furnish to the purchaser a chemical analysis report for the elements specified in Table 1.

98 **23.3** *EDI* — A certificate of inspection or chemical analysis report printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The use and format of the EDI document are subject to agreement between the purchaser and the supplier.

98 NOTE 8 — EDI is the computer to computer exchange of business information in a standard format such as ANSI ASC X12.

98 **23.4** Notwithstanding the absence of a signature, the organization submitting the certificate of inspection or chemical analysis report is responsible for its content.

24. Product Marking

98 **24.1** Each length of pipe shall be legibly marked by rolling, stamping, or stenciling to show: the name or brand of the manufacturer; the kind of pipe, that is, continuous-welded A, electric-resistance-welded A, electric-resistance-welded B, seamless A; or seamless B; XS for extra strong, XXS for double extra strong; the specification number; and the length. Length shall be marked in feet and tenths of a foot, or meters to two decimal places, depending on the units to which the material was ordered, or other marking subject to agreement. When requested by the purchaser, Type S and Type E pipe shall also be marked with the heat number. In addition, the marking of seamless pipe shall include the information given in Table 5.

24.2 For pipe NPS $1\frac{1}{2}$ and smaller which is bundled, this information may be marked on a tag securely attached to each bundle.

24.3 When pipe sections are cut into shorter lengths by a subsequent producer for resale as material, the processor shall transfer complete identification including the name or brand of the manufacturer, to each unmarked cut length, or to metal tags securely attached to unmarked pipe bundled in accordance with the requirements of 24.2. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

24.4 *Bar Coding* — In addition to the requirements in 24.1, 24.2, 24.3, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

25. Government Procurement

25.1 When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Federal Std. No. 183 if continuous marking is required, for military agencies.

25.2 *Inspection* — Unless otherwise specified in the contract, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the producer may use his own or any other suitable facilities for performing the inspection and test requirements specified herein, unless otherwise disapproved by the purchaser in the contract or purchase order. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where deemed necessary to ensure that the material conforms to prescribed requirements.

26. Packaging and Package Marking

26.1 When specified on the purchase order, packaging, marking, and loading or shipment shall be in accordance with those procedures recommended by Practices A 700.

27. Keywords 98

27.1 black steel pipe; seamless steel pipe; steel pipe; welded steel pipe; zinc coated steel pipe

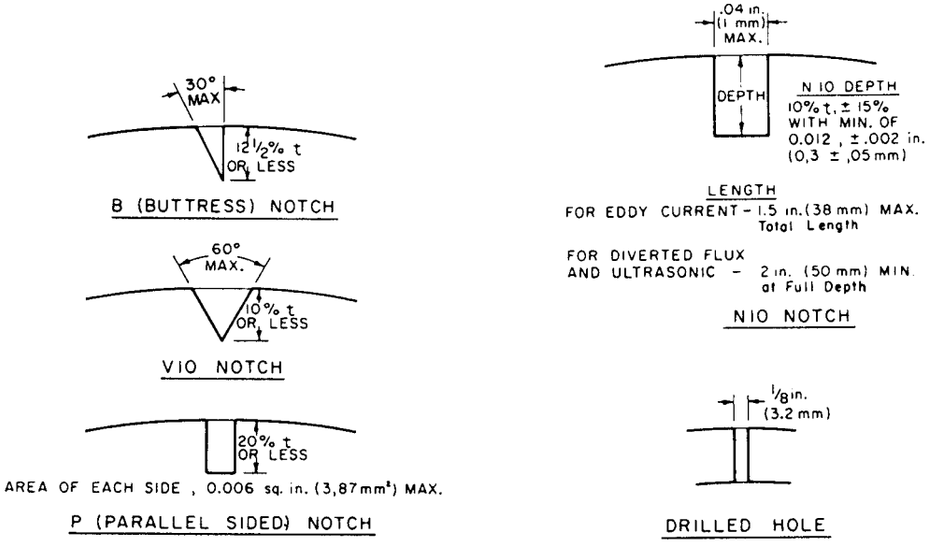


FIG. 1 REFERENCE STANDARDS

98

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, max, %								
	Carbon	Manganese	Phosphorus	Sulfur	Copper[A]	Nickel[A]	Chromium[A]	Molybdenum	Vanadium[A]
Type S (seamless pipe)									
Open-hearth, electric-furnace or basic-oxygen:									
Grade A	0.25	0.95	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Grade B	0.30	1.20	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Type E (electric-resistance-welded)									
Open-hearth, electric-furnace or basic-oxygen:									
Grade A	0.25	0.95	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Grade B	0.30	1.20	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Type F (furnace-welded pipe)									
Open-hearth, electric-furnace, or basic oxgen									
Grade A	0.30	1.20	0.05	0.045	0.40	0.40	0.40	0.15	0.08

[A] The combination of these five elements shall not exceed 1.00%

98

TABLE 2
TENSILE REQUIREMENTS

	Type F	Types E and S	
	Open-Hearth, Basic Oxygen, or Electric-Furnace	Grade A	Grade B
Tensile strength, min, psi (MPa)	48 000 (330)	48 000 (330)	60 000 (415)
Yield strength, min, psi (MPa)	30 000 (205)	30 000 (205)	35 000 (240)
Elongation in 2 in.	[A,B]	[A,B]	[A,B]

[A] The minimum elongation in 2 in. (50.8 mm) shall be that determined by the following equation:

$$e = 625\,000\ A^{0.2}/U^{0.9}$$

where:

e = minimum elongation in 2 in. (50.8 mm) in percent rounded to the nearest 0.5%,

A = cross-sectional area of the tension test specimen in square inches, based on specified outside diameter or nominal specimen width and specified wall thickness rounded to the nearest 0.01 in.^{2} if the area thus calculated is greater than 0.75 in.^{2}, then the value 0.75 shall be used, and

U = specified tensile strength, psi.

[B] See Table X4.1 for minimum elongation values for various size tension specimens and grades.

TABLE 3 98
FLATTENING REQUIREMENTS

Kind of Pipe	Distance between Plates, "*H*"
Butt-welded, Grade A	60% of outside diameter
Electric-resistance-welded, Grades A and B	one-third of outside diameter
Seamless, Grades A and B	to the distance *H*

TABLE 4 98
ACCEPTANCE LIMITS

	Size of Hole		Acceptance Limit
Type Notch	in.	mm	Signal, %
N10, V10	1/8	3.2	100
B.P.	. . .	. . .	80

TABLE 5 98
MARKING OF SEAMLESS PIPE

Hydro	NDE	Marking
Yes	No	Test pressure
No	Yes	NDE
Yes	Yes	Test Pressure/NDE

APPENDICES

(Nonmandatory Information)

X1. DEFINITIONS OF TYPES OF PIPE

X1.1 *Type F, Furnace-Butt-Welded Pipe, Continuous-Welded* — Pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round pass welding rolls.

X1.2 *Type E, Electric-Resistance-Welded Pipe* — Pipe produced in individual lengths or in continuous lengths from coiled skelp and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by the application of pressure.

X1.3 *Type S, Wrought Steel Seamless Pipe* — Wrought steel seamless pipe is a tubular product made without a welded seam. It is manufactured by hot working steel and, if necessary, by subsequently cold finishing the hot-worked tubular product to produce the desired shape, dimensions, and properties.

X2. TABLES FOR DIMENSIONAL AND CERTAIN MECHANICAL REQUIREMENTS

TABLE X2.1
CALCULATED *H* VALUES FOR SEAMLESS PIPE

NPS Designator	Outside Diameter, in. (mm)	Wall Thickness, in. (mm)	Distance, in. (mm), Between Plates "*H*" by Formula: $H = (1 + e)t/(e + t/D)$	
			Grade A	Grade B
2½	2.875 (73.0)	0.203 (5.16)	1.378 (35.0)	1.545 (39.2)
		0.276 (7.01)	1.618 (41.1)	1.779 (45.2)
3	3.500 (88.9)	0.216 (5.49)	1.552 (39.4)	1.755 (44.6)
		0.300 (7.62)	1.861 (47.3)	2.062 (52.4)
3½	4.000 (101.6)	0.226 (5.74)	1.682 (42.7)	1.912 (48.6)
		0.318 (8.08)	2.045 (51.9)	2.276 (57.8)
4	4.500 (114.3)	0.237 (6.02)	1.811 (46.0)	2.067 (52.5)
		0.337 (8.56)	2.228 (56.6)	2.489 (63.2)
5	5.563 (141.3)	0.258 (6.55)	2.062 (52.4)	2.372 (60.2)
		0.375 (9.52)	2.597 (66.0)	2.920 (74.2)
6	6.625 (168.3)	0.280 (7.11)	2.308 (58.6)	2.669 (67.8)
		0.432 (10.97)	3.034 (77.1)	3.419 (86.8)
8	8.625 (219.1)	0.277 (7.04)	2.473 (62.8)	2.902 (73.7)
		0.322 (8.18)	2.757 (70.0)	3.210 (81.5)
		0.500 (12.70)	3.683 (93.5)	4.181 (106.2)
10	10.750 (273.1)	0.279 (7.09)[A]	2.623 (66.6)	3.111 (79.0)
		0.307 (7.80)	2.823 (71.7)	3.333 (84.7)
		0.365 (9.27)	3.210 (81.5)	3.757 (95.4)
		0.500 (12.70)	3.993 (101.4)	4.592 (116.6)
12	12.750 (323.9)	0.300 (7.62)	3.105 (78.9)	3.683 (93.5)
		0.375 (9.52)	3.423 (86.9)	4.037 (102.5)
		0.500 (12.70)	4.218 (107.1)	4.899 (124.4)
14	14.000 (355.6)	0.375 (9.52)	3.500 (88.9)	4.146 (105.3)
		0.500 (12.70)	4.336 (110.1)	5.061 (128.5)
16	16.000 (406.4)	0.375 (9.52)	3.603 (91.5)	4.294 (109.1)
		0.500 (12.70)	4.494 (114.1)	5.284 (134.2)
18	18.000 (457)	0.375 (9.52)	3.688 (93.7)	4.417 (112.2)
		0.500 (12.70)	4.628 (117.6)	5.472 (139.0)
20	20.000 (508)	0.375 (9.52)	3.758 (95.5)	4.521 (114.8)
		0.500 (12.70)	4.740 (120.4)	5.632 (143.1)
24	24.000 (610)	0.375 (9.52)	3.869 (98.3)	4.686 (119.0)
		0.500 (12.70)	4.918 (124.9)	5.890 (149.6)

[A] Special order only.

TABLE X2.2
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE

98

NPS Designator	Outside Diameter, in. (mm)	Wall Thickness, in. (mm)	Nominal Weight per ft (m), Plain End, lb (kg)	Weight Class	Schedule No.	Test Pressure,[A] psi (kPa)	
						Grade A	Grade B
1/8	0.405 (10.3)	0.068 (1.73)	0.24 (0.37)	STD	40	700 (4830)	700 (4830)
		0.095 (2.41)	0.31 (0.47)	XS	80	850 (5860)	850 (5860)
1/4	0.540 (13.7)	0.088 (2.24)	0.42 (0.63)	STD	40	700 (4830)	700 (4830)
		0.119 (3.02)	0.54 (0.80)	XS	80	850 (5860)	850 (5860)
3/8	0.675 (17.1)	0.091 (2.31)	0.57 (0.84)	STD	40	700 (4830)	700 (4830)
		0.126 (3.20)	0.74 (1.10)	XS	80	850 (5860)	850 (5860)
1/2	0.840 (21.3)	0.109 (2.77)	0.85 (1.27)	STD	40	700 (4830)	700 (4830)
		0.147 (3.73)	1.09 (1.62)	XS	80	850 (5860)	850 (5860)
		0.188 (4.78)	1.31 (1.95)	. . .	160	900 (6210)	900 (6210)
		0.294 (7.47)	1.71 (2.55)	XXS	. . .	1000 (6890)	1000 (6890)
3/4	1.050 (26.7)	0.113 (2.87)	1.13 (1.69)	STD	40	700 (4830)	700 (4830)
		0.154 (3.91)	1.47 (2.20)	XS	80	850 (5860)	850 (5860)
		0.219 (5.56)	1.94 (2.90)	. . .	160	950 (6550)	950 (6550)
		0.308 (7.82)	2.44 (3.64)	XXS	. . .	1000 (6890)	1000 (6890)
1	1.315 (33.4)	0.133 (3.38)	1.68 (2.50)	STD	40	700 (4830)	700 (4830)
		0.179 (4.55)	2.17 (3.24)	XS	80	850 (5860)	850 (5860)
		0.250 (6.35)	2.84 (4.24)	. . .	160	950 (6550)	950 (6550)
		0.358 (9.09)	3.66 (5.45)	XXS	. . .	1000 (6890)	1000 (6890)
1 1/4	1.660 (42.2)	0.140 (3.56)	2.27 (3.39)	STD	40	1200 (8270)	1300 (8960)
		0.191 (4.85)	3.00 (4.47)	XS	80	1800 (12410)	1900 (13100)
		0.250 (6.35)	3.76 (5.61)	. . .	160	1900 (13100)	2000 (13790)
		0.382 (9.70)	5.21 (7.77)	XXS	. . .	2200 (15170)	2300 (15860)
1 1/2	1.900 (48.3)	0.145 (3.68)	2.72 (4.05)	STD	40	1200 (8270)	1300 (8960)
		0.200 (5.08)	3.63 (5.41)	XS	80	1800 (12410)	1900 (13100)
		0.281 (7.14)	4.86 (7.25)	. . .	160	1950 (13440)	2050 (14130)
		0.400 (10.16)	6.41 (9.56)	XXS	. . .	2200 (15170)	2300 (15860)
2	2.375 (60.3)	0.154 (3.91)	3.65 (5.44)	STD	40	2300 (15860)	2500 (17240)
		0.218 (5.54)	5.02 (7.48)	XS	80	2500 (17240)	2500 (17240)
		0.344 (8.74)	7.46 (11.11)	. . .	160	2500 (17240)	2500 (17240)
		0.436 (11.07)	9.03 (13.44)	XXS	. . .	2500 (17240)	2500 (17240)
2 1/2	2.875 (73.0)	0.203 (5.16)	5.79 (8.63)	STD	40	2500 (17240)	2500 (17240)
		0.276 (7.01)	7.66 (11.41)	XS	80	2500 (17240)	2500 (17240)
		0.375 (9.52)	10.01 (14.90)	. . .	160	2500 (17240)	2500 (17240)
		0.552 (14.02)	13.70 (20.39)	XXS	. . .	2500 (17240)	2500 (17240)
3	3.500 (88.9)	0.125 (3.18)	4.51 (6.72)	. . .	. . .	1290 (8890)	1500 (1030)
		0.156 (3.96)	5.57 (8.29)	. . .	. . .	1600 (11030)	1870 (12890)
		0.188 (4.78)	6.65 (9.92)	. . .	. . .	1930 (13310)	2260 (15580)
		0.216 (5.49)	7.58 (11.29)	STD	40	2220 (15310)	2500 (17240)
		0.250 (6.35)	8.68 (12.93)	. . .	. . .	2500 (17240)	2500 (17240)
		0.281 (7.14)	9.66 (14.40)	. . .	. . .	2500 (17240)	2500 (17240)
		0.300 (7.62)	10.25 (15.27)	XS	80	2500 (17240)	2500 (17240)
		0.438 (11.13)	14.32 (21.35)	. . .	160	2500 (17240)	2500 (17240)
		0.600 (15.24)	18.58 (27.68)	XXS	. . .	2500 (17240)	2500 (17240)
3 1/2	4.000 (101.6)	0.125 (3.18)	5.17 (7.72)	. . .	. . .	1120 (7720)	1310 (9030)
		0.156 (3.96)	6.40 (9.53)	. . .	. . .	1400 (9650)	1640 (11310)

98

TABLE X2.2 (CONT'D)
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE

NPS Designator	Outside Diameter, in. (mm)	Wall Thickness, in. (mm)	Nominal Weight per ft (m), Plain End, lb (kg)	Weight Class	Schedule No.	Test Pressure,[A] psi (kPa)	
						Grade A	Grade B
		0.188 (4.78)	7.65 (11.41)	...	...	1690 (11650)	1970 (13580)
		0.226 (5.74)	9.11 (13.57)	STD	40	2030 (14000)	2370 (16340)
		0.250 (6.35)	10.01 (14.92)	...	...	2250 (15510)	2500 (17240)
		0.281 (7.14)	11.16 (16.63)	...	...	2500 (17240)	2500 (17240)
		0.318 (8.08)	12.51 (18.63)	XS	80	2800 (19310)	2800 (19310)
4	4.500 (114.3)	0.125 (3.18)	5.84 (8.71)	...	...	1000 (6890)	1170 (8070)
		0.156 (3.96)	7.24 (10.78)	...	...	1250 (8620)	1460 (10070)
		0.188 (4.78)	8.66 (12.91)	...	...	1500 (10340)	1750 (12070)
		0.219 (5.56)	10.01 (14.91)	...	...	1750 (12070)	2040 (14070)
		0.237 (6.02)	10.79 (16.07)	STD	40	1900 (13100)	2210 (15240)
		0.250 (6.35)	11.35 (16.90)	...	...	2000 (13790)	2330 (16060)
		0.281 (7.14)	12.66 (18.87)	...	...	2250 (15110)	2620 (18060)
		0.312 (7.92)	13.98 (20.78)	...	...	2500 (17240)	2800 (19310)
		0.337 (8.56)	14.98 (22.32)	XS	80	2700 (18620)	2800 (19310)
		0.438 (11.13)	19.00 (28.32)	...	120	2800 (19310)	2800 (19310)
		0.531 (13.49)	22.51 (33.54)	...	160	2800 (19310)	2800 (19310)
		0.674 (17.12)	27.54 (41.03)	XXS	...	2800 (19310)	2800 (19310)
5	5.563 (141.3)	0.156 (3.96)	9.01 (13.41)	...	...	1010 (6960)	1180 (8140)
		0.188 (4.78)	10.79 (16.09)	...	...	1220 (8410)	1420 (9790)
		0.219 (5.56)	12.50 (18.61)	...	...	1420 (9790)	1650 (11380)
		0.258 (6.55)	14.62 (21.77)	STD	40	1670 (11510)	1950 (13440)
		0.281 (7.14)	15.85 (23.62)	...	...	1820 (12550)	2120 (14620)
		0.312 (7.92)	17.50 (26.05)	...	...	2020 (13930)	2360 (16270)
		0.344 (8.74)	19.17 (28.57)	...	...	2230 (15380)	2600 (17930)
		0.375 (9.52)	20.78 (30.94)	XS	80	2430 (16750)	2800 (19310)
		0.500 (12.70)	27.04 (40.28)	...	120	2800 (19310)	2800 (19310)
		0.625 (15.88)	32.96 (49.11)	...	160	2800 (19310)	2800 (19310)
		0.750 (19.05)	38.55 (57.43)	XXS	...	2800 (19310)	2800 (19310)
6	6.625 (168.3)	0.188 (4.78)	12.92 (19.27)	...	...	1020 (7030)	1190 (8200)
		0.219 (5.56)	14.98 (22.31)	...	...	1190 (8200)	1390 (9580)
		0.250 (6.35)	17.02 (25.36)	...	...	1360 (9380)	1580 (10890)
		0.280 (7.11)	18.97 (28.26)	STD	40	1520 (10480)	1780 (12270)
		0.312 (7.92)	21.04 (31.32)	...	...	1700 (11720)	1980 (13650)
		0.344 (8.74)	23.08 (34.39)	...	...	1870 (12890)	2180 (15030)
		0.375 (9.52)	25.03 (37.28)	...	...	2040 (14070)	2380 (16410)
		0.432 (10.97)	28.57 (42.56)	XS	80	2350 (16200)	2740 (18890)
		0.562 (14.27)	36.39 (54.20)	...	120	2800 (19310)	2800 (19310)
		0.719 (18.26)	45.35 (67.56)	...	160	2800 (19310)	2800 (19310)
		0.864 (21.95)	53.16 (79.22)	XXS	...	2800 (19310)	2800 (19310)
8	8.625 (219.1)	0.188 (4.78)	16.94 (25.26)	...	...	780 (5380)	920 (6340)
		0.203 (5.16)	18.26 (27.22)	...	...	850 (5860)	1000 (6890)
		0.219 (5.56)	19.66 (29.28)	...	...	910 (6270)	1070 (7380)
		0.250 (6.35)	22.36 (33.31)	...	20	1040 (7170)	1220 (8410)
		0.277 (7.04)	24.70 (36.31)	...	30	1160 (7800)	1350 (9310)
		0.312 (7.92)	27.70 (41.24)	...	...	1300 (8960)	1520 (10480)
		0.322 (8.18)	28.55 (42.55)	STD	40	1340 (9240)	1570 (10820)
		0.344 (8.74)	30.42 (45.34)	...	...	1440 (9930)	1680 (11580)
		0.375 (9.52)	33.04 (49.20)	...	...	1570 (10820)	1830 (12620)
		0.406 (10.31)	35.64 (53.08)	...	60	1700 (11720)	2000 (13790)
		0.438 (11.13)	38.30 (57.08)	...	...	1830 (12620)	2130 (14690)
		0.500 (12.70)	43.39 (64.64)	XS	80	2090 (14410)	2430 (16750)
		0.594 (15.09)	50.95 (75.92)	...	100	2500 (17240)	2800 (19310)

TABLE X2.2 (CONT'D) 98
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE

NPS Designator	Outside Diameter, in. (mm)	Wall Thickness, in. (mm)	Nominal Weight per ft (m), Plain End, lb (kg)	Weight Class	Schedule No.	Test Pressure,[A] psi (kPa)	
						Grade A	Grade B
		0.719 (18.26)	60.71 (90.44)	. . .	120	2800 (19310)	2800 (19310)
		0.812 (20.62)	67.76 (100.92)	. . .	140	2800 (19310)	2800 (19310)
		0.875 (22.22)	72.42 (107.88)	XXS	. . .	2800 (19310)	2800 (19310)
		0.906 (23.01)	74.69 (111.27)	. . .	160	2800 (19310)	2800 (19310)
10	10.750 (273.0)	0.188 (4.78)	21.21 (31.62)	. . .	. . .	630 (4340)	730 (5030)
		0.203 (5.16)	22.87 (34.08)	. . .	. . .	680 (4690)	800 (5520)
		0.219 (5.56)	24.63 (36.67)	. . .	. . .	730 (5030)	860 (5930)
		0.250 (6.35)	28.04 (41.75)	. . .	20	840 (5790)	980 (6760)
		0.279 (7.09)	31.20 (46.49)	. . .	. . .	930 (6410)	1090 (7520)
		0.307 (7.80)	34.24 (51.01)	. . .	30	1030 (7100)	1200 (8270)
		0.344 (8.74)	38.23 (56.96)	. . .	. . .	1150 (7930)	1340 (9240)
		0.365 (9.27)	40.48 (60.29)	STD	40	1220 (8410)	1430 (9860)
		0.438 (11.13)	48.19 (71.87)	. . .	. . .	1470 (10140)	1710 (11790)
		0.500 (12.70)	54.74 (81.52)	XS	60	1670 (11510)	1950 (13440)
		0.594 (15.09)	64.43 (95.97)	. . .	80	1990 (13720)	2320 (16000)
		0.719 (18.26)	77.03 (114.70)	. . .	100	2410 (16620)	2800 (19310)
		0.844 (21.44)	89.29 (133.00)	. . .	120	2800 (19310)	2800 (19310)
		1.000 (25.40)	104.13 (155.09)	XXS	140	2800 (19310)	2800 (19310)
		1.125 (28.57)	115.65 (172.21)	. . .	160	2800 (19310)	2800 (19310)
12	12.750 (323.8)	0.203 (5.16)	27.20 (40.55)	. . .	. . .	570 (3930)	670 (4620)
		0.219 (5.56)	29.31 (43.63)	. . .	. . .	620 (4270)	720 (4960)
		0.250 (6.35)	33.38 (49.71)	. . .	20	710 (4900)	820 (5650)
		0.281 (7.14)	37.42 (55.75)	. . .	. . .	790 (5450)	930 (6410)
		0.312 (7.92)	41.45 (61.69)	. . .	. . .	880 (6070)	1030 (7100)
		0.330 (8.38)	43.77 (65.18)	. . .	30	930 (6410)	1090 (7520)
		0.344 (8.74)	45.58 (67.90)	. . .	. . .	970 (6690)	1130 (7790)
		0.375 (9.52)	49.56 (73.78)	STD	. . .	1060 (7310)	1240 (8550)
		0.406 (10.31)	53.52 (79.70)	. . .	40	1150 (7930)	1340 (9240)
		0.438 (11.13)	57.59 (85.82)	. . .	. . .	1240 (8550)	1440 (9930)
		0.500 (12.70)	65.42 (97.43)	XS	. . .	1410 (9720)	1650 (11380)
		0.562 (14.27)	73.15 (108.92)	. . .	60	1590 (10960)	1850 (12760)
		0.688 (17.48)	88.63 (132.04)	. . .	80	1940 (13380)	2270 (15650)
		0.844 (21.44)	107.32 (159.86)	. . .	100	2390 (16480)	2780 (19170)
		1.000 (25.40)	125.49 (186.91)	XXS	120	2800 (19310)	2800 (19310)
		1.125 (28.57)	139.68 (208.00)	. . .	140	2800 (19310)	2800 (19310)
		1.312 (33.32)	160.27 (238.68)	. . .	160	2800 (19310)	2800 (19310)
14	14.000 (355.6)	0.210 (5.33)	30.93 (46.04)	. . .	. . .	540 (3720)	630 (4340)
		0.219 (5.56)	32.23 (47.99)	. . .	. . .	560 (3860)	660 (4550)
		0.250 (6.35)	36.71 (54.69)	. . .	10	640 (4410)	750 (5170)
		0.281 (7.14)	41.17 (61.35)	. . .	. . .	720 (4960)	840 (5790)
		0.312 (7.92)	45.61 (67.90)	. . .	20	800 (5520)	940 (6480)
		0.344 (8.74)	50.17 (74.76)	. . .	. . .	880 (6070)	1030 (7100)
		0.375 (9.52)	54.57 (81.25)	STD	30	960 (6620)	1120 (7720)
		0.438 (11.13)	63.44 (94.55)	. . .	40	1130 (7790)	1310 (9030)
		0.469 (11.91)	67.78 (100.94)	. . .	. . .	1210 (8340)	1410 (9720)
		0.500 (12.70)	72.09 (107.39)	XS	. . .	1290 (8890)	1500 (10340)
		0.594 (15.09)	85.05 (126.71)	. . .	60	1530 (10550)	1790 (12340)
		0.750 (19.05)	106.13 (158.10)	. . .	80	1930 (13310)	2250 (15510)
		0.938 (23.83)	130.85 (194.96)	. . .	100	2410 (16620)	2800 (19310)
		1.094 (27.79)	150.79 (224.65)	. . .	120	2800 (19310)	2800 (19310)
		1.250 (31.75)	170.22 (253.56)	. . .	140	2800 (19310)	2800 (19310)
		1.406 (35.71)	189.11 (281.70)	. . .	160	2800 (19310)	2800 (19310)
		2.000 (50.80)	256.32 (381.83)	. . .	. . .	2800 (19310)	2800 (19310)

98

TABLE X2.2 (CONT'D)
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE

NPS Designator	Outside Diameter, in. (mm)	Wall Thickness, in. (mm)	Nominal Weight per ft (m), Plain End, lb (kg)	Weight Class	Schedule No.	Test Pressure,[A] psi (kPa)	
						Grade A	Grade B
		2.125 (53.97)	269.51 (401.44)	...	...	2800 (19310)	2800 (19310)
		2.200 (55.88)	277.26 (413.01)	...	...	2800 (19310)	2800 (19310)
		2.500 (63.50)	307.05 (457.40)	...	...	2800 (19310)	2800 (19310)
16	16.000 (406.4)	0.219 (5.56)	36.91 (54.96)	...	...	490 (3380)	570 (3930)
		0.250 (6.35)	42.05 (62.64)	...	10	560 (3860)	660 (4550)
		0.281 (7.14)	47.17 (70.30)	...	...	630 (4340)	740 (5100)
		0.312 (7.92)	52.27 (77.83)	...	20	700 (4830)	820 (5650)
		0.344 (8.74)	57.52 (85.71)	...	...	770 (5310)	900 (6210)
		0.375 (9.52)	62.58 (93.17)	STD	30	840 (5790)	980 (6760)
		0.438 (11.13)	72.80 (108.49)	...	...	990 (6830)	1150 (7930)
		0.469 (11.91)	77.79 (115.86)	...	...	1060 (7310)	1230 (8480)
		0.500 (12.70)	82.77 (123.30)	XS	40	1120 (7720)	1310 (9030)
		0.656 (16.66)	107.50 (160.12)	...	60	1480 (10200)	1720 (11860)
		0.844 (21.44)	136.62 (203.53)	...	80	1900 (13100)	2220 (15310)
		1.031 (26.19)	164.82 (245.56)	...	100	2320 (16000)	2710 (18680)
		1.219 (30.96)	192.43 (286.64)	...	120	2740 (18890)	2800 (19310)
		1.438 (36.53)	223.64 (333.19)	...	140	2800 (19310)	2800 (19310)
		1.594 (40.49)	245.25 (366.35)	...	160	2800 (19310)	2800 (19310)
18	18.000 (457.2)	0.250 (6.35)	47.39 (70.60)	...	10	500 (3450)	580 (4000)
		0.281 (7.14)	53.18 (79.24)	...	...	560 (3860)	660 (4550)
		0.312 (7.92)	58.94 (87.75)	...	20	620 (4270)	730 (5030)
		0.344 (8.74)	64.87 (96.66)	...	...	690 (4760)	800 (5520)
		0.375 (9.52)	70.59 (105.10)	STD	...	750 (5170)	880 (6070)
		0.406 (10.31)	76.29 (113.62)	...	...	810 (5580)	950 (6550)
		0.438 (11.13)	82.15 (122.43)	...	30	880 (6070)	1020 (7030)
		0.469 (11.91)	87.81 (130.78)	...	...	940 (6480)	1090 (7520)
		0.500 (12.70)	93.45 (139.20)	XS	...	1000 (6890)	1170 (8070)
		0.562 (14.27)	104.67 (155.87)	...	40	1120 (7720)	1310 (9030)
		0.750 (19.05)	138.17 (205.83)	...	60	1500 (10340)	1750 (12070)
		0.938 (23.83)	170.92 (254.67)	...	80	1880 (12960)	2190 (15100)
		1.156 (29.36)	207.96 (309.76)	...	100	2310 (15930)	2700 (18620)
		1.375 (34.92)	244.14 (363.64)	...	120	2750 (18960)	2800 (19310)
		1.562 (39.67)	274.22 (408.45)	...	140	2800 (19310)	2800 (19310)
		1.781 (45.24)	308.50 (459.59)	...	160	2800 (19310)	2800 (19310)
20	20.000 (508.0)	0.250 (6.35)	52.73 (78.55)	...	10	450 (3100)	520 (3590)
		0.281 (7.14)	59.18 (88.19)	...	...	510 (3520)	590 (4070)
		0.312 (7.92)	65.60 (97.67)	...	...	560 (3860)	660 (4550)
		0.344 (8.74)	72.21 (107.60)	...	...	620 (4270)	720 (4960)
		0.375 (9.52)	78.60 (117.02)	STD	20	680 (4690)	790 (5450)
		0.406 (10.31)	84.96 (126.53)	...	...	730 (5030)	850 (5860)
		0.438 (11.13)	91.51 (135.37)	...	...	790 (5450)	920 (6340)
		0.469 (11.91)	97.83 (145.70)	...	...	850 (5860)	950 (6550)
		0.500 (12.70)	104.13 (155.12)	XS	30	900 (6210)	1050 (7240)
		0.594 (15.09)	123.11 (183.42)	...	40	1170 (8070)	1250 (8620)
		0.812 (20.62)	166.40 (247.83)	...	60	1460 (10070)	1710 (11790)
		1.031 (26.19)	208.87 (311.17)	...	80	1860 (12820)	2170 (14960)
		1.281 (32.54)	256.10 (381.53)	...	100	2310 (15930)	2690 (18550)
		1.500 (38.10)	296.37 (441.49)	...	120	2700 (18620)	2800 (19310)
		1.750 (44.45)	341.10 (508.11)	...	140	2800 (19310)	2800 (19310)
		1.969 (50.01)	379.10 (564.81)	...	160	2800 (19310)	2800 (19310)
24	24.000 (609.6)	0.250 (6.35)	63.41 (94.46)	...	10	380 (2620)	440 (3030)
		0.281 (7.14)	71.18 (106.08)	...	...	420 (2900)	490 (3380)

TABLE X2.2 (CONT'D)
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR PLAIN END PIPE

98

NPS Designator	Outside Diameter, in. (mm)	Wall Thickness, in. (mm)	Nominal Weight per ft (m), Plain End, lb (kg)	Weight Class	Schedule No.	Test Pressure,[A] psi (kPa)	
						Grade A	Grade B
		0.312 (7.92)	78.93 (117.51)	. . .	. . .	470 (3240)	550 (3790)
		0.344 (8.74)	86.91 (129.50)	. . .	. . .	520 (3590)	600 (4140)
		0.375 (9.52)	94.62 (140.88)	STD	20	560 (3860)	660 (4550)
		0.406 (10.31)	102.31 (152.37)	. . .	. . .	610 (4210)	710 (4900)
		0.438 (11.13)	110.22 (164.26)	. . .	. . .	660 (4550)	770 (5310)
		0.469 (11.91)	117.86 (175.54)	. . .	. . .	700 (4830)	820 (5650)
		0.500 (12.70)	125.49 (186.94)	XS	. . .	750 (5170)	880 (6070)
		0.562 (14.27)	140.68 (209.50)	. . .	30	840 (5790)	980 (6760)
		0.688 (17.48)	171.29 (255.24)	. . .	40	1030 (7100)	1200 (8270)
		0.938 (23.83)	231.03 (344.23)	. . .	. . .	1410 (9720)	1640 (11310)
		0.969 (24.61)	238.85 (355.02)	. . .	60	1450 (10000)	1700 (11720)
		1.219 (30.96)	296.58 (441.78)	. . .	80	1830 (12620)	2130 (14690)
		1.531 (38.89)	367.39 (547.33)	. . .	100	2300 (15860)	2680 (18480)
		1.812 (46.02)	429.39 (639.58)	. . .	120	2720 (18750)	2800 (19310)
		2.062 (52.37)	483.12 (719.63)	. . .	140	2800 (19310)	2800 (19310)
		2.344 (59.54)	542.14 (807.63)	. . .	160	2800 (19310)	2800 (19310)
26	26.000 (660.4)	0.250 (6.35)	68.75 (102.42)	. . .	. . .	350 (2410)	400 (2760)
		0.281 (7.14)	77.18 (115.02)	. . .	. . .	390 (2690)	450 (3100)
		0.312 (7.92)	85.60 (127.43)	. . .	10	430 (2960)	500 (3450)
		0.344 (8.74)	94.26 (140.45)	. . .	. . .	480 (3310)	560 (3860)
		0.375 (9.52)	102.63 (152.80)	STD	. . .	520 (3590)	610 (4210)
		0.406 (10.31)	110.98 (165.28)	. . .	. . .	560 (3860)	660 (4550)
		0.438 (11.13)	119.57 (178.20)	. . .	. . .	610 (4210)	710 (4900)
		0.469 (11.91)	127.88 (190.46)	. . .	. . .	650 (4480)	760 (5240)
		0.500 (12.70)	136.17 (202.85)	XS	20	690 (4760)	810 (5580)
		0.562 (14.27)	152.68 (227.37)	. . .	. . .	780 (5380)	910 (6270)

[A] The minimum test pressure for outside diameters and wall thickness not listed shall be computed by the formula given below. The computed test pressure shall be used in all cases with the following exceptions:

(1) When the wall thickness is greater than the heaviest wall thickness shown for a given diameter, the test pressure for the heaviest wall listed shall be the required test pressure.

(2) For Grades A and B in sizes under NPS 2 and for all sizes continuous-welded, when the wall thickness is lighter than the lightest shown for a given diameter, use the test pressure given for the lightest wall thickness of the table for the diameter involved.

(3) For all sizes of continuous-welded pipe and all sizes of Grade A and B pipe smaller than NPS 2, the test pressure has been arbitrarily assigned. Test pressures for intermediate outside diameters need not exceed those for the next larger listed size.

$$P = 2St/D$$

where:
P = minimum hydrostatic test pressure, psi (kPa),
S = 0.60 times the minimum specified yield point, psi (kPa),
t = specified wall thickness, in. (mm), and
D = specified outside diameter, in. (mm).

98

TABLE X2.3
DIMENSIONS, WEIGHTS, AND TEST PRESSURES FOR THREADED AND COUPLED PIPE

NPS Designator	Outside Diameter, in. (mm)	Wall Thickness, in. (mm)	Nominal Weight per ft (m), Threads and Couplings, lb (kg)	Weight Class	Schedule No.	Test Pressure,[4] psi (kPa)	
						Grade A	Grade B
1/8	0.405 (10.3)	0.068 (1.73)	0.24 (0.37)	STD	40	700 (4830)	700 (4830)
		0.095 (2.41)	0.32 (0.46)	XS	80	850 (5860)	850 (5860)
1/4	0.540 (13.7)	0.088 (2.24)	0.42 (0.63)	STD	40	700 (4830)	700 (4830)
		0.119 (3.02)	0.54 (0.80)	XS	80	850 (5860)	850 (5860)
3/8	0.675 (17.1)	0.091 (2.31)	0.57 (0.84)	STD	40	700 (4830)	700 (4830)
		0.126 (3.20)	0.74 (1.10)	XS	80	850 (5860)	850 (5860)
1/2	0.840 (21.3)	0.109 (2.77)	0.85 (1.27)	STD	40	700 (4830)	700 (4830)
		0.147 (3.73)	1.09 (1.62)	XS	80	850 (5860)	850 (5860)
		0.294 (7.47)	1.72 (2.54)	XXS	. . .	1000 (6890)	1000 (6890)
3/4	1.050 (26.7)	0.113 (2.87)	1.13 (1.69)	STD	40	700 (4830)	700 (4830)
		0.154 (3.91)	1.48 (2.21)	XS	80	850 (5860)	850 (5860)
		0.308 (7.82)	2.44 (3.64)	XXS	. . .	1000 (6890)	1000 (6890)
1	1.315 (33.4)	0.133 (3.38)	1.68 (2.50)	STD	40	700 (4830)	700 (4830)
		0.179 (4.55)	2.18 (3.25)	XS	80	850 (5860)	850 (5860)
		0.358 (9.09)	3.66 (5.45)	XXS	. . .	1000 (6890)	1000 (6890)
1 1/4	1.660 (42.2)	0.140 (3.56)	2.28 (3.40)	STD	40	1000 (6890)	1100 (7580)
		0.191 (4.85)	3.02 (4.49)	XS	80	1500 (10340)	1600 (11030)
		0.382 (9.70)	5.22 (7.76)	XXS	. . .	1800 (12410)	1900 (13100)
1 1/2	1.900 (48.3)	0.145 (3.68)	2.73 (4.04)	STD	40	1000 (6890)	1100 (7580)
		0.200 (5.08)	3.66 (5.39)	XS	80	1500 (10340)	1600 (11030)
		0.400 (10.16)	6.41 (9.56)	XXS	. . .	1800 (12410)	1900 (13100)
2	2.375 (60.3)	0.154 (3.91)	3.68 (5.46)	STD	40	2300 (15860)	2500 (17240)
		0.218 (5.54)	5.07 (7.55)	XS	80	2500 (17240)	2500 (17240)
		0.436 (11.07)	9.03 (13.44)	XXS	. . .	2500 (17240)	2500 (17240)
2 1/2	2.875 (73.0)	0.203 (5.16)	5.82 (8.67)	STD	40	2500 (17240)	2500 (17240)
		0.276 (7.01)	7.73 (11.52)	XS	80	2500 (17240)	2500 (17240)
		0.552 (14.02)	13.70 (20.39)	XXS	. . .	2500 (17240)	2500 (17240)
3	3.500 (88.9)	0.216 (5.49)	7.62 (11.35)	STD	40	2200 (15170)	2500 (17240)
		0.300 (7.62)	10.33 (15.39)	XS	80	2500 (17240)	2500 (17240)
		0.600 (15.24)	18.57 (27.66)	XXS	. . .	2500 (17240)	2500 (17240)
3 1/2	4.000 (101.6)	0.226 (5.74)	9.20 (13.71)	STD	40	2000 (13790)	2400 (16550)
		0.318 (8.08)	12.63 (18.82)	XS	80	2800 (19310)	2800 (19310)
4	4.500 (114.3)	0.237 (6.02)	10.89 (16.23)	STD	40	1900 (13100)	2200 (15170)
		0.337 (8.56)	15.17 (22.60)	XS	80	2700 (18620)	2800 (19310)
		0.674 (17.12)	27.58 (41.09)	XXS	. . .	2800 (19310)	2800 (19310)
5	5.563 (141.3)	0.258 (6.55)	14.81 (22.07)	STD	40	1700 (11720)	1900 (13100)
		0.375 (9.52)	21.09 (31.42)	XS	80	2400 (16550)	2800 (19310)
		0.750 (19.05)	38.61 (57.53)	XXS	. . .	2800 (19310)	2800 (19310)
6	6.625 (168.3)	0.280 (7.11)	19.18 (28.58)	STD	40	1500 (10340)	1800 (12410)
		0.432 (10.97)	28.89 (43.05)	XS	80	2300 (15860)	2700 (18620)
		0.864 (21.95)	53.14 (79.18)	XXS	. . .	2800 (19310)	2800 (19310)
8	8.625 (219.1)	0.277 (7.04)	25.55 (38.07)	. . .	30	1200 (8270)	1300 (8960)
		0.322 (8.18)	29.35 (43.73)	STD	40	1300 (8960)	1600 (11030)
		0.500 (12.70)	43.90 (65.41)	XS	80	2100 (14480)	2400 (16550)
		0.875 (22.22)	72.44 (107.94)	XXS	. . .	2800 (19310)	2800 (19310)
10	10.750 (273.0)	0.279 (7.09)	32.75 (48.80)	. . .	. . .	950 (6550)	1100 (7580)
		0.307 (7.80)	35.75 (53.27)	. . .	30	1000 (6890)	1200 (8270)
		0.365 (9.27)	41.85 (63.36)	STD	40	1200 (8270)	1400 (9650)
		0.500 (12.70)	55.82 (83.17)	XS	60	1700 (11720)	2000 (13790)
12	12.750 (323.8)	0.330 (8.38)	45.45 (67.72)	. . .	30	950 (6550)	1100 (7580)
		0.375 (9.52)	51.15 (76.21)	STD	. . .	1100 (7580)	1200 (8270)
		0.500 (12.70)	66.71 (99.40)	XS	. . .	1400 (9650)	1600 (11030)

TABLE X2.4
TABLE OF MINIMUM WALL THICKNESSES ON INSPECTION FOR NOMINAL (AVERAGE) PIPE WALL THICKNESSES

98

NOTE 1 — The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:
t_n = nominal (average) wall thickness, in. (mm), and
t_m = minimum wall thickness, in. (mm).

The wall thickness is expresssed to three decimal places the fourth decimal place being carried forward or dropped in accordance with Practice E 29.

NOTE 2 — This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Nominal (Average) Thickness (t_n), in. (mm)	Minimum Thickness on Inspection (t_m), in. (mm)	Nominal (Average) Thickness (t_n), in. (mm)	Minimum Thickness on Inspection (t_m), in. (mm)	Nomional (Average) Thickness (t_n), in. (mm)	Minimum Thickness on Inspection (t_m), in. (mm)
0.068 (1.73)	0.060 (1.52)	0.294 (7.47)	0.257 (6.53)	0.750 (19.05)	0.656 (16.66)
0.088 (2.24)	0.077 (1.96)	0.300 (7.62)	0.262 (6.65)	0.812 (20.62)	0.710 (18.03)
0.091 (2.31)	0.080 (2.03)	0.307 (7.80)	0.269 (6.83)	0.844 (21.44)	0.739 (18.77)
0.095 (2.41)	0.083 (2.11)	0.308 (7.82)	0.270 (6.86)	0.864 (21.94)	0.756 (19.20)
0.109 (2.77)	0.095 (2.41)	0.312 (7.92)	0.273 (6.93)	0.875 (22.22)	0.766 (19.46)
0.113 (2.87)	0.099 (2.51)	0.318 (8.08)	0.278 (7.06)	0.906 (23.01)	0.793 (20.14)
0.119 (3.02)	0.104 (2.64)	0.322 (8.18)	0.282 (7.16)	0.938 (23.82)	0.821 (20.85)
0.125 (3.18)	0.109 (2.77)	0.330 (8.38)	0.289 (7.34)	0.968 (24.59)	0.847 (21.51)
0.126 (3.20)	0.110 (2.79)	0.337 (8.56)	0.295 (7.49)	1.000 (25.40)	0.875 (22.22)
0.133 (3.38)	0.116 (2.95)	0.343 (8.71)	0.300 (7.62)	1.031 (26.19)	0.902 (22.91)
0.140 (3.56)	0.122 (3.10)	0.344 (8.74)	0.301 (7.65)	1.062 (26.97)	0.929 (26.30)
0.145 (3.68)	0.127 (3.23)	0.358 (9.09)	0.313 (7.95)	1.094 (27.79)	0.957 (24.31)
0.147 (3.73)	0.129 (3.28)	0.365 (9.27)	0.319 (8.10)	1.125 (28.58)	0.984 (24.99)
0.154 (3.91)	0.135 (3.43)	0.375 (9.52)	0.328 (8.33)	1.156 (29.36)	1.012 (25.70)
0.156 (3.96)	0.136 (3.45)	0.382 (9.70)	0.334 (8.48)	1.219 (30.96)	1.067 (27.08)
0.179 (4.55)	0.157 (3.99)	0.400 (10.16)	0.350 (8.89)	1.250 (31.75)	1.094 (27.79)
0.187 (4.75)	0.164 (4.17)	0.406 (10.31)	0.355 (9.02)	1.281 (32.54)	1.121 (28.47)
0.188 (4.78)	0.164 (4.17)	0.432 (10.97)	0.378 (9.60)	1.312 (33.32)	1.148 (29.16)
0.191 (4.85)	0.167 (4.24)	0.436 (11.07)	0.382 (9.70)	1.343 (34.11)	1.175 (29.85)
0.200 (5.08)	0.175 (4.44)	0.437 (11.10)	0.382 (9.70)	1.375 (34.92)	1.203 (30.56)
0.203 (5.16)	0.178 (4.52)	0.438 (11.13)	0.383 (9.73)	1.406 (35.71)	1.230 (31.24)
0.216 (5.49)	0.189 (4.80)	0.500 (12.70)	0.438 (11.13)	1.438 (36.53)	1.258 (31.95)
0.218 (5.54)	0.191 (4.85)	0.531 (13.49)	0.465 (11.81)	1.500 (38.10)	1.312 (33.32)
0.219 (5.56)	0.192 (4.88)	0.552 (14.02)	0.483 (12.27)	1.531 (38.89)	1.340 (34.04)
0.226 (5.74)	0.198 (5.03)	0.562 (14.27)	0.492 (12.50)	1.562 (39.67)	1.367 (34.72)
0.237 (6.02)	0.207 (5.26)	0.594 (15.09)	0.520 (13.21)	1.594 (40.49)	1.395 (35.43)
0.250 (6.35)	0.219 (5.56)	0.600 (15.24)	0.525 (13.34)	1.750 (44.45)	1.531 (38.89)
0.258 (6.55)	0.226 (5.74)	0.625 (15.88)	0.547 (13.89)	1.781 (45.24)	1.558 (39.57)
0.276 (7.01)	0.242 (6.15)	0.656 (16.66)	0.574 (14.58)	1.812 (46.02)	1.586 (40.28)
0.277 (7.04)	0.242 (6.15)	0.674 (17.12)	0.590 (14.99)	1.968 (49.99)	1.722 (43.74)
0.279 (7.09)	0.244 (6.20)	0.688 (17.48)	0.602 (15.29)	2.062 (52.37)	1.804 (45.82)
0.280 (7.11)	0.245 (6.22)	0.719 (18.26)	0.629 (15.98)	2.344 (59.54)	2.051 (52.10)
0.281 (7.14)	0.246 (6.25)				

X3. BASIC THREADING DATA

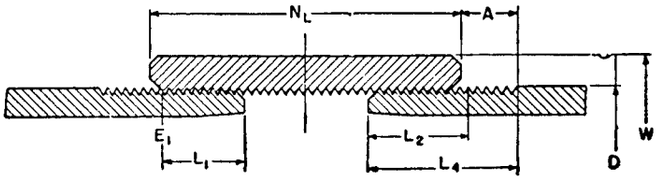


FIG. X3.1 DIMENSIONS OF HAND TIGHT ASSEMBLY FOR USE WITH TABLE X3.1

TABLE X3.1
BASIC THREADING DATA FOR STANDARD-WEIGHT NPS 6 AND UNDER

NOTE 1 — All dimensions in this table are nominal and subject to mill tolerances.
NOTE 2 — The taper of threads is 3/4 in./ft (62.5 mm/m) on the diameter.

Pipe		Threads					Coupling		
NPS Designator	Outside Diameter, in. *D*	Number per inch	End of Pipe to Hand Tight Plane, in.[A] L_1	Effective Length, in.[A] L_2	Total Length in.[A] L_4	Pitch Diameter at Hand Tight Plane, in.[A] E_1	Outside Diameter, in.[A] W	Length, in. min.[A] N_L	Hand Tight Stand-Off (Number of Threads) A
1/8	0.405	27	0.1615	0.2638	0.3924	0.37360	0.563	3/4	4
1/4	0.540	18	0.2278	0.4018	0.5946	0.49163	0.719	1 1/8	5 1/2
3/8	0.675	18	0.240	0.4078	0.6006	0.62701	0.875	1 1/8	5
1/2	0.840	14	0.320	0.5337	0.7815	0.77843	1.063	1 1/2	5
3/4	1.050	14	0.339	0.5457	0.7935	0.98887	1.313	1 9/16	5
1	1.315	11 1/2	0.400	0.6828	0.9845	1.23863	1.576	1 15/16	5
1 1/4	1.660	11 1/2	0.420	0.7068	1.0085	1.58338	1.900	2	5
1 1/2	1.900	11 1/2	0.420	0.7235	1.0252	1.82234	2.200	2	5 1/2
2	2.375	11 1/2	0.436	0.7565	1.0582	2.29627	2.750	2 1/16	5 1/2
2 1/2	2.875	8	0.682	1.1376	1.5712	2.76216	3.250	3 1/16	5 1/2
3	3.500	8	0.766	1.2000	1.6337	3.38850	4.000	3 2/16	5 1/2
3 1/2	4.000	8	0.821	1.2500	1.6837	3.88881	4.625	3 5/16	5 1/2
4	4.500	8	0.844	1.3000	1.7337	4.38713	5.000	3 7/16	5
5	5.563	8	0.937	1.4063	1.8400	5.44929	6.296	3 11/16	5
6	6.625	8	0.958	1.5125	1.9462	6.50597	7.390	4 15/16	6

[A] 1 in. = 25.4 mm.

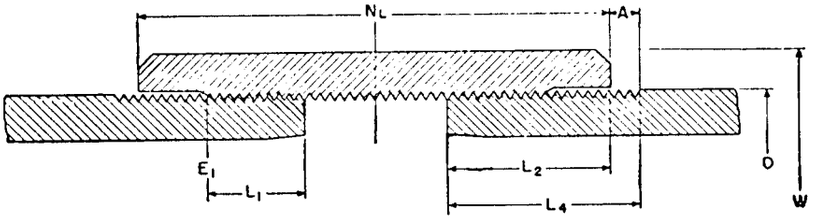


FIG. X3.2 DIMENSIONS OF HAND TIGHT ASSEMBLY FOR USE WITH TABLE X3.2

TABLE X3.2
BASIC THREADING DATA FOR STANDARD-WEIGHT PIPE IN NPS 8 AND LARGER, AND ALL SIZES OF EXTRA-STRONG AND DOUBLE-EXTRA-STRONG WEIGHT

NOTE — The taper of threads is 3/4 in./ft (62.5 mm/m) on the diameter.

Pipe		Threads					Coupling		
NPS Designator	Outside Diameter, in. *D*	Number per inch	End of Pipe to Hand Tight Plane, in.[A] L_1	Effective Length, in.[A] L_2	Total Length in.[A] L_4	Pitch Diameter at Hand Tight Plane, in.[A] E_1	Outside Diameter, in.[A] W	Length, in. min.[A] N_L	Hand Tight Stand-Off (Number of Threads)
1/8	0.405	27	0.1615	0.2638	0.3924	0.37360	0.563	1 1/16	3
1/4	0.540	18	0.2278	0.4018	0.5946	0.49163	0.719	1 5/8	3
3/8	0.675	18	0.240	0.4078	0.6006	0.62701	0.875	1 5/8	3
1/2	0.840	14	0.320	0.5337	0.7815	0.77843	1.063	2 1/8	3
3/4	1.050	14 1/2	0.339	0.5457	0.7935	0.98887	1.313	2 1/8	3
1	1.315	11	0.400	0.6828	0.9845	1.23863	1.576	2 5/8	3
1 1/4	1.660	11 1/2	0.420	0.7068	1.0085	1.58338	2.054	2 3/4	3
1 1/2	1.900	11 1/2	0.420	0.7235	1.0252	1.82234	2.200	2 3/4	3
2	2.375	11 1/2	0.436	0.7565	1.0582	2.29627	2.875	2 7/8	3
2 1/2	2.875	8	0.682	1.1375	1.5712	2.76216	3.375	4 1/8	2
3	3.500	8	0.766	1.2000	1.6337	3.38850	4.000	4 1/4	2
3 1/2	4.000	8	0.821	1.2500	1.6837	3.88881	4.625	4 3/8	2
4	4.500	8	0.844	1.3000	1.7337	4.38713	5.200	4 1/2	2
5	5.563	8	0.937	1.4063	1.8400	5.44929	6.296	4 5/8	2
6	6.625	8	0.958	1.5125	1.9462	6.50597	7.390	4 7/8	2
8	8.625	8	1.063	1.7125	2.1462	8.50003	9.625	5 1/4	2
10	10.750	8	1.210	1.9250	2.3587	10.62094	11.750	5 3/4	2
12	12.750	8	1.360	2.1250	2.5587	12.61781	14.000	6 1/8	2
14	14.000	8	1.562	2.2500	2.6837	13.87263	15.000	6 3/8	2
16	16.000	8	1.812	2.4500	2.8837	15.87575	17.000	6 3/4	2
18	18.000	8	2.000	2.6500	3.0837	17.87500	19.000	7 1/8	2
20[A]	20.000	8	2.125	2.8500	3.2837	19.87031	21.000	7 5/8	2

[A] 1 in. = 25.4 mm.

X4. ELONGATION VALUES

98 **X4.1** Tabulated in Table X4.1 are the minimum elongation values calculated by the equation given in Table 2.

TABLE X4.1
ELONGATION VALUES

Area, *A*, in.[2,A]	Tension Test Specimen: Specified Wall Thickness, in.[B] ¾-in. Specimen	1-in. Specimen	1½-in. Specimen	Elongation in 2 in., min, %: Specified Tensile Strength, psi 45 000	48 000	60 000
0.75 and greater	0.994 and greater	0.746 and greater	0.497 and greater	38.5	36.0	29.5
0.74	0.980–0.993	0.735–0.745	0.490–0.496	38.0	36.0	29.5
0.73	0.967–0.979	0.726–0.734	0.484–0.489	38.0	36.0	29.5
0.72	0.954–0.966	0.715–0.725	0.477–0.483	38.0	36.0	29.5
0.71	0.941–0.953	0.706–0.714	0.471–0.476	38.0	35.5	29.0
0.70	0.927–0.940	0.695–0.705	0.464–0.470	38.0	35.5	29.0
0.69	0.914–0.926	0.686–0.694	0.457–0.463	37.5	35.5	29.0
0.68	0.900–0.913	0.675–0.685	0.450–0.456	37.5	35.5	29.0
0.67	0.887–0.899	0.666–0.674	0.444–0.449	37.5	35.5	29.0
0.66	0.874–0.886	0.655–0.665	0.437–0.443	37.5	35.0	29.0
0.65	0.861–0.873	0.646–0.654	0.431–0.436	37.0	35.0	28.5
0.64	0.847–0.860	0.635–0.645	0.424–0.430	37.0	35.0	28.5
0.63	0.834–0.846	0.626–0.634	0.417–0.423	37.0	35.0	28.5
0.62	0.820–0.833	0.615–0.625	0.410–0.416	37.0	35.0	28.5
0.61	0.807–0.819	0.606–0.614	0.404–0.409	36.5	34.5	28.5
0.60	0.794–0.806	0.595–0.605	0.397–0.403	36.5	34.5	28.5
0.59	0.781–0.793	0.586–0.594	0.391–0.396	36.5	34.5	28.0
0.58	0.767–0.780	0.575–0.585	0.384–0.390	36.5	34.5	28.0
0.57	0.754–0.766	0.566–0.574	0.377–0.383	36.0	34.0	28.0
0.56	0.740–0.753	0.555–0.565	0.370–0.376	36.0	34.0	28.0
0.55	0.727–0.739	0.546–0.554	0.364–0.369	36.0	34.0	28.0
0.54	0.714–0.726	0.535–0.545	0.357–0.363	36.0	34.0	27.5
0.53	0.701–0.713	0.526–0.534	0.351–0.356	35.5	33.5	27.5
0.52	0.687–0.700	0.515–0.525	0.344–0.350	35.5	33.5	27.5
0.51	0.674–0.686	0.506–0.514	0.337–0.343	35.5	33.5	27.5
0.50	0.660–0.673	0.495–0.505	0.330–0.336	35.5	33.5	27.0
0.49	0.647–0.659	0.486–0.494	0.324–0.329	35.0	33.0	27.0
0.48	0.634–0.646	0.475–0.485	0.317–0.323	35.0	33.0	27.0
0.47	0.621–0.633	0.466–0.474	0.311–0.316	35.0	33.0	27.0
0.46	0.607–0.620	0.455–0.465	0.304–0.310	34.5	33.0	27.0
0.45	0.594–0.606	0.446–0.454	0.297–0.303	34.5	32.5	26.5
0.44	0.580–0.593	0.435–0.445	0.290–0.296	34.5	32.5	26.5
0.43	0.567–0.579	0.426–0.434	0.284–0.289	34.5	32.5	26.5
0.42	0.554–0.566	0.415–0.425	0.277–0.283	34.0	32.0	26.5
0.41	0.541–0.553	0.406–0.414	0.271–0.276	34.0	32.0	26.0
0.40	0.527–0.540	0.395–0.405	0.264–0.270	34.0	32.0	26.0
0.39	0.514–0.526	0.386–0.394	0.257–0.263	33.5	31.5	26.0
0.38	0.500–0.513	0.375–0.385	0.250–0.256	33.5	31.5	26.0
0.37	0.487–0.499	0.366–0.374	0.244–0.249	33.0	31.5	25.5
0.36	0.474–0.486	0.355–0.365	0.237–0.243	33.0	31.0	25.5
0.35	0.461–0.473	0.346–0.354	0.231–0.236	33.0	31.0	25.5
0.34	0.447–0.460	0.335–0.345	0.224–0.230	32.5	31.0	25.0
0.33	0.434–0.446	0.326–0.334	0.217–0.223	32.5	30.5	25.0
0.32	0.420–0.433	0.315–0.325	0.210–0.216	32.5	30.5	25.0

TABLE X4.1 (CONT'D)
ELONGATION VALUES

Area, A, in.^{2} [A]	Tension Test Specimen — Specified Wall Thickness, in.[B]			Elongation in 2 in., min, % — Specified Tensile Strength, psi		
	$\frac{3}{4}$-in. Specimen	1-in. Specimen	$1\frac{1}{2}$-in. Specimen	45 000	48 000	60 000
0.31	0.407–0.419	0.306–0.314	0.204–0.209	32.0	30.5	25.0
0.30	0.394–0.406	0.295–0.305	0.197–0.203	32.0	30.0	24.5
0.29	0.381–0.393	0.286–0.294	0.191–0.196	31.5	30.0	24.5
0.28	0.367–0.380	0.275–0.285	0.184–0.190	31.5	29.5	24.5
0.27	0.354–0.366	0.266–0.274	0.177–0.183	31.0	29.5	24.0
0.26	0.340–0.353	0.255–0.265	0.170–0.176	31.0	29.0	24.0
0.25	0.327–0.339	0.246–0.254	0.164–0.169	30.5	29.0	23.5
0.24	0.314–0.326	0.235–0.245	0.157–0.163	30.5	29.0	23.5
0.23	0.301–0.313	0.226–0.234	0.151–0.156	30.0	28.5	23.5
0.22	0.287–0.300	0.215–0.225	0.144–0.150	30.0	28.5	23.0
0.21	0.274–0.286	0.206–0.214	0.137–0.143	29.5	28.0	23.0
0.20	0.260–0.273	0.195–0.205	0.130–0.136	29.5	27.5	22.5
0.19	0.247–0.259	0.186–0.194	0.124–0.129	29.0	27.5	22.5
0.18	0.234–0.246	0.175–0.185	0.117–0.123	29.0	27.0	22.0
0.17	0.221–0.233	0.166–0.174	0.111–0.116	28.5	27.0	22.0
0.16	0.207–0.220	0.155–0.165	0.104–0.110	28.0	26.5	21.5
0.15	0.194–0.206	0.146–0.154	0.097–0.103	27.5	26.0	21.5
0.14	0.180–0.193	0.135–0.145	0.091–0.096	27.5	26.0	21.0
0.13	0.167–0.179	0.126–0.134	0.084–0.090	27.0	25.5	21.0
0.12	0.154–0.166	0.115–0.125	0.077–0.083	26.5	25.0	20.5
0.11	0.141–0.153	0.106–0.114	0.071–0.076	26.0	24.5	20.0
0.10	0.127–0.140	0.095–0.105	0.064–0.070	25.5	24.0	19.5
0.09	0.114–0.126	0.086–0.094	0.057–0.063	25.0	23.5	19.5
0.08	0.100–0.113	0.075–0.085	0.050–0.056	24.5	23.0	19.0
0.07	0.087–0.099	0.066–0.074	0.044–0.049	24.0	22.5	18.5
0.06	0.074–0.086	0.055–0.065	0.037–0.043	23.0	22.0	18.0
0.05	0.061–0.073	0.046–0.054	0.031–0.036	22.5	21.0	17.0
0.04	0.047–0.060	0.035–0.045	0.024–0.030	21.5	20.0	16.5
0.03	0.034–0.046	0.026–0.034	0.017–0.023	20.0	19.0	15.5
0.02	0.020–0.033	0.015–0.025	0.010–0.016	18.5	17.5	14.5
0.01 and less	0.019 and less	0.014 and less	0.009 and less	16.0	15.0	12.5

[A] 1 in.^{2} = 645.16 mm^{2}.
[B] 1 in. = 25.4 mm.

SPECIFICATION FOR CARBON STEEL FORGINGS FOR PIPING APPLICATIONS 98

SA-105/SA-105M

(Identical with ASTM Specification A 105/A 105M-96) 98

1. Scope

1.1 This specification covers forged carbon steel piping components for ambient- and higher-temperature service in pressure systems. Included are flanges, fittings, valves, and similar parts ordered either to dimensions specified by the purchaser or to dimensional standards such as the ANSI and API specifications referenced in Section 2. Forgings made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. Larger forgings may be ordered to Specification A 266. Tubesheets and hollow cylindrical forgings for pressure vessel shells are not included within the scope of this specification. Although this specification covers some piping components machined from rolled bar and seamless tubular products, (see 4.4) it does not cover raw material produced in these product forms.

1.2 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.3 Specification A 266/A 266M covers other steel forgings and Specifications A 675, A 695, and A 696 cover other steel bars.

1.4 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*

A 266/A 266M Specification for Forgings, Carbon Steel, for Pressure Vessel Components

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 675 Specification for Steel Bars, Carbon, Hot Wrought, Special Quality, Mechanical Properties

A 695 Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, for Fluid Power Applications

A 696 Specification for Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 788 Specification for Steel Forgings, General Requirements

E 165 Practice for Liquid Penetrant Inspection Method

E 340 Test Method for Macroetching Metals and Alloys

2.2 *MSS Standards:*
SP25 Standard Marking System for Valves, Fittings, Flanges and Unions
SP44 Standard for Steel Pipe Line Flanges

2.3 *ASME Standard:*
Section IX, Welding Qualifications, ASME Boiler and Pressure Vessel Code

2.4 *ANSI Standards:*
B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings
B16.9 Wrought Steel Buttwelding Fittings
B16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves
B16.11 Forged Steel Fittings, Socket Weld, and Threaded
B16.34 Valves-Flanged, Threaded and Welding End

2.5 *API Standards:*
API-600 Flanged and Butt-Welding-End Steel Gate Valves
API-602 Compact Design Carbon Steel Gate Valves for Refinery Use

2.6 *AWS Standard:*
AWS A5.1 Mild Steel Covered Arc-Welding Electrodes

98 **3. Ordering Information**

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information as necessary to purchase the needed material. Examples of such information include but are not limited to the following:

3.1.1 Quantity,

3.1.2 Size and pressure class or dimensions (Tolerances and surface finishes should be included),

3.1.3 Specification number (The year date should be included),

3.1.4 Supplementary requirements, and

3.1.5 Additional requirements (See Table 1 footnotes, 12.1, and 16.2).

4. Materials and Manufacture

4.1 The steel shall be made by the open-hearth, basic-oxygen, or electric-furnace process and shall be fully killed.

4.2 A sufficient discard shall be made from source material to secure freedom from injurious piping and undue segregation.

4.3 The material shall be forged as close as practicable to the specified shape and size.

4.4 Except for flanges of all types, hollow cylindrically shaped parts may be machined from hot-rolled bar, forged bar, or seamless tubular material provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Other parts (up to and including NPS 4) not including flanges may be machined from hot-rolled or forged bar. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.5 Except as permitted by 4.4, the finished product shall be a forging as defined in the Terminology Section of Specification A 788.

5. Heat Treatment

5.1 Heat treatment is not a mandatory requirement of this specification except for the following piping components:

5.1.1 Flanges above Class 300,

5.1.2 Flanges of special design where the design pressure at the design temperature exceeds the pressure–temperature ratings of Class 300, Group 1.1,

5.1.3 Flanges of special design where the design pressure or design temperature are not known,

5.1.4 Piping components other than flanges which meet both of the following criteria: *(1)* over NPS 4 and *(2)* above Class 300, and

5.1.5 Piping components of Special Class other than flanges which meet both of the following criteria: *(1)* over NPS 4 and *(2)* when the working pressure at the operating temperature exceeds the tabulated values for Special Class 300, Group 1.1.

5.2 Heat treatment when required by 5.1 shall be annealing, normalizing, or normalizing and tempering or quenching and tempering.

5.2.1 *Annealing* — The procedure for annealing shall consist of allowing the forgings immediately after forging or rolling, to cool to a temperature below 1000°F [538°C]. They shall then be reheated to a temperature between 1550°F [843°C] and 1700°F [927°C] to refine the grain (a group thus reheated being

known as an "annealing charge") and allowed to cool uniformly in the furnace.

5.2.2 *Normalizing* — The procedure for normalizing shall consist of allowing the forgings, immediately after forging or rolling, to cool to a temperature below 1000°F [538°C]. They shall then be uniformly reheated to a temperature between 1550°F [843°C] and 1700°F [927°C] to refine the grain (a group thus reheated being known as a "normalizing charge") and allowed to cool in air.

5.2.3 *Tempering* — The procedure for tempering shall consist of heating the forgings to a temperature between 1100°F [593°C] and the lower transformation temperature for a minimum of ½ h/in. [½ h/25.4 mm] of maximum section thickness.

5.2.4 *Quenching* — The procedure for quenching shall consist of either *(1)* fully austenitizing the forgings followed by quenching in a suitable liquid medium or *(2)* using a multiple stage procedure whereby the forging is first fully austenitized and rapidly cooled, then reheated to partially reaustenitize, followed by quenching in a suitable liquid medium. All quenched forgings shall be tempered as prescribed in 5.2.3.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements specified in Table 1. Test Methods, Practices and Terminology A 751 shall apply.

6.2 Steels to which lead has been added shall not be used.

7. Cast or Heat (Formerly Ladle) Analysis

7.1 An analysis of each heat of steel shall be made from samples taken, preferably during the pouring of the heat, and the results shall conform with Table 1.

8. Product Analysis

8.1 The purchaser may make a product analysis on forgings supplied to this specification. Samples for analysis may be taken from midway between center and surface of solid forgings, midway between inner and outer surfaces of hollow forgings, midway between center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 1 within the tolerances stated in Table 2.

9. Mechanical Properties

9.1 The material shall conform to the mechanical property requirements prescribed in Tables 3 and 4.

9.2 For the purpose of determining conformance with Tables 3 and 4, specimens shall be obtained from production forgings after heat treatment, when heat treatment is required, or from separately forged test blanks prepared from the stock used to make the finished product. Such test blanks shall receive approximately the same working as the finished product. The test blanks shall be heat treated with the finished product.

9.3 For normalized, normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the ¼ *T* plane or deeper position, where *T* is the maximum heat-treated thickness of the represented forging. In addition, for quenched and tempered forgings, the midlength of the test specimen shall be at least *T* from any second heat-treated surface. When section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location.

9.4 *Tension Tests:*

9.4.1 One tension test shall be made for each heat of as-forged components.

9.4.2 One tension test shall be made from each heat-treating charge. If more than one heat is included in such a charge, each heat shall be tested. **98**

9.4.2.1 When the heat-treating temperatures are the same and the furnaces (either batch or continuous type), are controlled within ±25°F [±14°C] and equipped with recording pyrometers so that complete records of heat treatment are available, then one tension test from each heat is required instead of one test from each heat in each heat-treatment charge. The test specimen material shall be included with a furnace charge.

9.4.3 Testing shall be performed in accordance with Test Methods and Definitions A 370. The largest feasible round specimen as described in Test Methods and Definitions A 370 shall be used except when hollow cylindrically shaped parts are machined from seamless tubulars. The gage length for measuring elongation shall be four times the diameter of the test section. When hollow cylindrically shaped parts are machined from seamless tubular materials, strip tests may be used.

9.4.4 Forgings too small to permit obtaining a subsize specimen of 0.250 in. [6.35 mm] diameter or

larger (see Test Methods and Definitions A 370) parallel to the dimension of maximum working, and produced in equipment unsuitable for production of a separately forged test bar such as an automatic or semi-automatic press, may be accepted on the basis of hardness only. One percent of the forgings per lot (see Note 2), or ten forgings, whichever is the lesser number, shall be selected at random, prepared, and tested using the standard Brinell test in Test Methods and Definitions A 370. The locations of the indentations shall be at the option of the manufacturer but shall be selected to be representative of the forging as a whole. One indentation per forging shall be required but additional indentations may be made to establish the representative hardness. The hardness of all forgings so tested shall be 137 to 187 HB inclusive.

NOTE 2 — A lot is defined as the product from a mill heat or if heat treated, the product of a mill heat per furnace charge.

98 **9.5** *Hardness Tests* — Except when only one forging is produced, a minimum of two forgings shall be hardness tested per batch or continuous run as defined in 9.4.2.1 to ensure that forgings are within the hardness limits given in Table 3. When only one forging is produced, it shall be hardness tested as defined in 9.4.2.1 to ensure it is within the hardness limits given in Table 3. Testing shall be in accordance with Test Methods and Definitions A 370. The purchaser may verify that the requirement has been met by testing at any location on the forging, provided such testing does not render the forging useless.

10. Hydrostatic Tests

10.1 Forgings manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished forging. Such tests shall be conducted by the forging manufacturer only when Supplementary Requirement S7 is specified.

11. Retreatment

11.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may heat treat or reheat treat the forgings as applicable and repeat the test specified in Section 9.

12. Workmanship, Finish, and Appearance

12.1 The forgings shall be free of injurious imperfections, as defined below, and shall have a workmanlike finish. At the discretion of the inspector representing the purchaser, finished forgings shall be subject to rejection if surface imperfections acceptable under 12.3 are not scattered but appear over a large area in excess of what is considered a workmanlike finish. Unless otherwise specified in the purchase order, the fittings shall be cleaned to remove all scale and processing compounds prior to final surface examination. The cleaning process shall not injure the surface finish, material properties, or the metallurgical structure. The cleaned fittings shall be protected to prevent recontamination. Protective coatings on socket weld and butt welding fittings shall be suitable for subsequent welding without removal of the coating. When specified in the purchase order, parts may be furnished in the as-formed or as-forged condition.

12.2 *Depth of Injurious Imperfection* — Selected typical linear and other typical surface imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness of the finished forging, such imperfections shall be considered injurious.

12.3 *Machining or Grinding Imperfections Not Classified as Injurious* — Surface imperfections not classified as injurious shall be treated as follows:

12.3.1 Forgings showing seams, laps, tears, or slivers not deeper than 5% of the nominal wall thickness or $\frac{1}{16}$ in. [1.6 mm], whichever is less, need not have these imperfections removed. If the imperfections require removal, they shall be removed by machining or grinding.

12.3.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed the limitations set forth in 12.2 and if not deeper than $\frac{1}{16}$ in. [1.6 mm]. If such imperfections are deeper than $\frac{1}{16}$ in. [1.6 mm], but do not encroach on the minimum wall thickness of the forging, they shall be removed by grinding to sound metal.

12.3.3 When imperfections have been removed by grinding or machining, the outside dimension at the point of grinding or machining may be reduced by the amount removed. Should it be impracticable to secure a direct measurement, the wall thickness at the point of grinding, or at imperfections not required to be removed, shall be determined by deducting the amount removed by grinding from the nominal finished wall thickness of forging, and the remainder shall not be less than the minimum specified or required wall thickness.

13. Repair by Welding

13.1 Repair of defects by the manufacturer is permissible for forgings made to dimensional standards such as those of ANSI or for other parts made for stock by the manufacturer. Prior approval of the purchaser is required to repair-weld special forgings made to the purchaser's requirements.

13.2 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

13.3 Weld repairs shall be made by a process that does not produce undesirably high levels of hydrogen in the welded areas.

13.4 Defects shall be completely removed by chipping or grinding to sound metal as verified by magnetic particle inspection prior to welding.

13.5 After repair welding, the area welded shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic-particle or liquid-penetrant inspection.

13.6 All forgings repaired by welding shall be post-weld heat treated between 1100°F [593°C] and the lower transformation temperature for a minimum of ½ h/in. [½ h/25.4 mm] of maximum section thickness, or alternatively annealed, normalized and tempered, or quenched and tempered. If the forging was not previously heat treated, the original tempering temperature was exceeded, or the forging was fully heat treated in the post weld cycle, then the forging shall be tested in accordance with Section 9 on completion of the cycle.

13.7 The mechanical properties of the procedure-qualification weldment shall, when tested in accordance with Section IX of the ASME Boiler and Pressure Vessel Code, conform with the requirements listed in Table 3 for the thermal condition of repair-welded forgings.

13.8 Repair by welding shall not exceed 10% of the surface area of the forging nor 33⅓% of the wall thickness of the finished forging or ⅜ in. [10 mm] whichever is less, without prior approval of the purchaser.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with the purchase order. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

15. Rejection and Rehearing

15.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

15.2 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

16. Certification

16.1 *Identification Marking* — For forgings made to specified dimensions, when agreed upon by the purchaser, and for forgings made to dimensional standards, application of identification marks as required in 17.1 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification. The specification designation included on test reports shall include year of issue and revision letter, if any.

16.2 *Test Reports* — When test reports are required, the manufacturer shall also provide the following, where applicable:

16.2.1 Type heat treatment, Section 5,

16.2.2 Tensile property results, Section 9 (Table 2), report the yield strength and ultimate strength in ksi [MPa], elongation and reduction in area, in percent,

16.2.3 Chemical analysis results, Section 6 (Table 1). When the amount of an unspecified element is less than 0.02%, then the analysis for that element may be reported as "<0.02%,"

16.2.4 Hardness results, Section 9 (Table 3), and

16.2.5 Any supplementary testing required by the purchase order.

17. Product Marking

17.1 Identification marks consisting of the manufacturer's symbol or name (see Note 3), the heat number or manufacturer's heat identificaion, designation of service rating, this specification number, and size shall be forged or legibly stamped on each forging, and in such a position as not to injure the usefullness of the forging.

The Standard Marking System of Valves, Fittings, Flanges, and Unions (SP-25-1978) of the Manufacturers' Standardization Society of the Valve and Fittings Industry may be followed except the word "Steel" shall not be substituted for this specification number.

NOTE 3 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

17.1.1 If the forgings have been quenched and tempered, the letters "QT" shall be stamped on the forgings following this specification number.

17.1.2 Forgings repaired by welding shall be marked with the letter "W" following this specification number.

17.2 When test reports are required for larger products, the markings shall consist of the manufacturer's symbol or name, this specification number, and such other markings as necessary to identify the part with the test report (17.1.1 and 17.1.2 shall apply). The specification number marked on the forgings need not include specification year of issue and revision letter.

17.3 *Bar Coding*—In addition to the requirements in 17.1 and 17.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag. **98**

98

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %
Carbon	0.35 max
Manganese	0.60–1.05
Phosphorus	0.035 max
Sulfur	0.040 max
Silicon	0.10–0.35
Copper	0.40 max [Note (1)]
Nickel	0.40 max [Note (1)]
Chromium	0.30 max [Notes (1)(2)]
Molybdenum	0.12 max [Notes (1)(2)]
Vanadium	0.05 max
Columbium	0.02 max

General Note—For each reduction of 0.01% below the specified carbon maximum (0.35%), an increase of 0.06% manganese above the specified maximum (1.05%) will be permitted up to a maximum of 1.35%.

NOTES:
(1) The sum of copper, nickel, chromium and molybdenum shall not exceed 1.00%.
(2) The sum of chromium and molybdenum shall not exceed 0.32%.

TABLE 2
PERMISSIBLE VARIATIONS IN PRODUCT ANALYSIS

	Permissible Variations over the Maximum Limit or Under the Minimum Limit, %				
	200 in.^{2} [1290 cm^2] and Under	Over 200 to 400 in.^{2} [1290 to 2580 cm^2], incl	Over 400 to 800 in.^{2} [2580 to 5160 cm^2], incl	Over 800 to 1600 in.^{2} [5160 to 10 320 cm^2] incl	Over 1600 in.^{2} [10 320 cm^2]
Carbon	0.02	0.03	0.04	0.05	0.05
Manganese:					
Up to and including 0.90	0.04	0.05	0.06	0.07	0.08
0.91 and over	0.06	0.07	0.08	0.08	0.09
Phosphorus	0.008	0.010	0.010	0.015	0.015
Sulfur	0.010	0.010	0.010	0.015	0.015
Silicon	0.03	0.04	0.04	0.05	0.06
Copper	0.03	0.03	0.03	0.03	0.03
Nickel	0.03	0.03	0.03	0.03	0.03
Chromium	0.04	0.04	0.04	0.04	0.04
Molybdenum	0.01	0.01	0.01	0.01	0.01
Vanadium	0.01	0.01	0.01	0.01	0.01
Colombium	0.01	0.01	0.01	0.01	0.01

General Notes—Product cross-sectional area (taken at right angles to the axis of the original ingot or billet) is defined as either:
(a) maximum cross-sectional area of rough machined forging (excluding boring),
(b) maximum cross-sectional area of the unmachined forging, or
(c) maximum cross-sectional area of the billet, bloom or slab.

TABLE 3
MECHANICAL REQUIREMENTS [Note (1)]

Tensile strength, min, psi [MPa]	70 000 [485]
Yield strength, min, psi [MPa] [Note (2)]	36 000 [250]
Elongation in 2 in. or 50 mm, min, %:	
Basic minimum elongation for walls $\frac{5}{16}$ in. [7.9 mm] and over in thickness, strip tests.	30
When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimen with the gage length equal to 4D is used	22
For strip tests, a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [7.9 mm] from the basic minimum elongation of the percentage points of Table 4	1.50 [Note (3)]
Reduction of area, min, % [Note (4)]	30
Hardness, HB, max	187

NOTES:
(1) For small forgings, see 9.4.4.
(2) Determined by either the 0.2% offset method or the 0.5% extension-under-load method.
(3) See Table 4 for computed minimum values.
(4) For round specimens only.

98

TABLE 4
COMPUTED MINIMUM VALUES

Wall Thickness		Elongation in 2 in. or 50 mm, min, %
in.	mm	
5/16 (0.312)	7.9	30.00
9/32 (0,281)	7.1	28.50
1/4 (0.250)	6.4	27.00
7/32 (0.219)	5.6	25.50
3/16 (0.188)	4.8	24.00
5/32 (0.156)	4.0	22.50
1/8 (0.125)	3.2	21.00
3/32 (0.094)	2.4	19.50
1/16 (0.062)	1.6	18.00

General Note:
The above table gives the computed minimum elongation values for each 1/32-in. [0.8-mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

$$E = 48T + 15.00$$

where:

E = elongation in 2 in. or 50 mm, %, and
T = actual thickness of specimen, in. [mm].

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Macroetch Test

S1.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted in accordance with Test Method E 340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Product Analysis

S2.1 A product analysis shall be made from one randomly selected forging representing each size and shape of forging on the order, and the results shall comply with Table 1. If the analysis fails to comply, each forging shall be checked or the lot rejected. All results shall be reported to the purchaser.

S3. Hardness

S3.1 The purchaser may check the hardness of any or all forgings supplied at any location on the forging and the hardness shall be 137 to 187 HB. All forgings not within the specified hardness range shall be rejected.

S4. Tension Tests

S4.1 In addition to the requirements of Section 9, the heat identification shall be marked on each forging and one tensile specimen shall be obtained from a representative forging at a location agreed upon between the manufacturer and the purchaser. The results of the test shall comply with Table 3 and shall be reported to the purchaser.

S5. Magnetic-Particle Examination

S5.1 All accessible surfaces of the finished forging shall be examined by a magnetic-particle method. The method shall be in accordance with Test Method A 275/A 275M. Acceptance limits shall be as agreed upon between the manufacturer and purchaser.

S6. Liquid-Penetrant Examination

S6.1 All surfaces shall be examined by a liquid-penetrant method. The method shall be in accordance with Practice E 165. Acceptance limits shall be as agreed upon by the manufacturer and the purchaser.

S7. Hydrostatic Testing

S7.1 A hydrostatic test at a pressure agreed upon by the manufacturer and the purchaser shall be applied by the manufacturer.

S8. Repair Welding

S8.1 No repair welding shall be permitted without prior approval of the purchaser.

S9. Heat Treatment

S9.1 All forgings shall be heat treated as specified by the purchaser. **98**

S9.2 When forgings not requiring heat treatment by 5.1 are supplied heat treated by purchaser request, the basis for determining conformance with Table 3 and Table 4 shall be hardness testing per 9.5 and either (*1*) tensile testing of heat treated forgings per 9.2, or (*2*) tensile tests from as-forged forgings or separately forged test blanks, as agreed upon between the supplier and purchaser. **98**

S9.3 When test reports are required, and tensile test results were obtained from as-forged forgings or as-forged test blanks, it shall be so indicated on the test report. **98**

S9.4 In addition to the marking required by Section 17, this specification shall be followed by the letter: A for annealed, N for normalized, NT for normalized and tempered, or QT for quenched and tempered as appropriate. **98**

S10. Marking Small Forgings

S10.1 For small products where the space for marking is less than 1 in. [25 mm] in any direction, test reports are mandatory and marking may be restricted to only such symbols or codes as are necessary to identify the parts with the test reports.

S10.2 When the configuration or size does not permit marking directly on the forging, the marking method shall be a matter of agreement between the manufacturer and the purchaser.

S11. Carbon Equivalent

S11.1 The maximum carbon equivalent, based on heat analysis, shall be 0.47 for forgings with a maximum section thickness of 2 in. or less, and 0.48 for forgings with a maximum section thickness of greater than 2 in.

S11.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S11.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

SPECIFICATION FOR SEAMLESS CARBON STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

SA-106

(Identical with ASTM A 106-95 except for editorial differences in 8.1, 13.4, and 24.1 and the deletion of ASTM caveat 1.5.) **98**

1. Scope

1.1 This specification covers seamless carbon steel pipe for high-temperature service (Note 1) in NPS $\frac{1}{8}$ to NPS 48 inclusive, with nominal (average) wall thickness as given in ANSI B36.10. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification. Pipe ordered under this specification shall be suitable for bending, flanging, and similar forming operations, and for welding. When the steel is to be welded, it is presupposed that a welding procedure suitable to the grade of steel and intended use or service will be utilized (Note 2).

NOTE 1 — Consideration should be given to possible graphitization of the material at the higher temperatures at which it may be used.

NOTE 2 — Grade A rather than Grade B or Grade C pipe should be used for close coiling, or cold bending. The purpose for which the pipe is to be used should be stated in the order. This note is not intended to prohibit the cold bending of Grade B seamless pipe.

1.2 Supplementary requirements (S1 to S4) of an optional nature are provided for seamless pipe intended for use in applications where a superior grade of pipe is required. These supplementary requirements call for additional tests to be made and when desired shall be so stated in the order.

1.3 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520 (Mechanical Property Requirements Section) shall supplement and supersede the requirements of this specification.

1.4 The values stated in inch-pound units are to be regarded as the standard.

NOTE 3 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.5 DELETED

2. Referenced Documents

2.1 *ASTM Standards:*

A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E 381 Method of Macrotech Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ANSI Standard:*

ANSI B36.10 Welded and Seamless Wrought Steel Pipe

2.3 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.4 *Federal Standard:*

Fed. Std. 123 Marking for Shipments (Civil Agencies)

Fed. Std. 183 Continuous Identification Marking of Iron and Steel Products

2.5 *Other Standards:*
SSPC-SP6 Surface Preparation Specification No. 6

3. Ordering Information

3.1 Orders for materials under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet or number of lengths),

3.1.2 Name of material (seamless carbon steel pipe),

3.1.3 Grade (Table 1),

3.1.4 Manufacture (hot-finished or cold-drawn),

3.1.5 Size (either NPS and weight class or schedule number, or both, or outside diameter and nominal wall thickness, ANSI B36.10),

3.1.6 Length (specific or random, Section 20),

3.1.7 Optional requirements (Section 9 and S1 to S4),

3.1.8 Test report required (Section on Certification of Specification A 530/A 530M),

3.1.9 Specification designation,

3.1.10 End use of material,

3.1.11 Hydrostatic test in accordance with Specification A 530/A 530M or 13.3 of this specification, or NDE in accordance with Section 14 of this specification.

3.1.12 Special requirements.

98 4. Process

4.1 The steel shall be killed steel made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting, using electroslag remelting or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand case, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 Pipe NPS $1\frac{1}{2}$ and under may be either hot finished or cold drawn.

4.4 Unless otherwise specified, pipe NPS 2 and over shall be furnished hot finished. When agreed upon between the manufacturer and the purchaser, cold-drawn pipe may be furnished.

5. Heat Treatment 98

5.1 Hot-finished pipe need not be heat treated. Cold-drawn pipe shall be heat treated after the final cold draw pass at a temperature of 1200°F (650°C) or higher.

6. General Requirements 98

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

7. Chemical Composition

7.1 The steel shall conform to the requirements as 98
to chemical composition prescribed in Table 1.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified in Section 7. If the secondary melting processes of 4.1 are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7.

9. Product Analysis

9.1 At the request of the purchaser, analyses of two pipes from each lot (Note 4) of 400 lengths or fraction thereof, of each size up to, but not including, NPS 6, and from each lot of 200 lengths or fraction thereof of each size NPS 6 and over, shall be made by the

manufacturer from the finished pipe. The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 7.

9.2 If the analysis of one of the tests specified in 9.1 does not conform to the requirements specified in Section 7, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to requirements specified.

NOTE 4 — A lot shall consist of the number of lengths specified in Sections 9 and 20 of the same size and wall thickness from any one heat of steel.

10. Tensile Requirements

98 **10.1** The material shall conform to the requirements as to tensile properties prescribed in Tables 2 and 3.

11. Bending Requirements

98 **11.1** For pipe NPS 2 and under a sufficient length of pipe shall stand being bent cold through 90° around a cylindrical mandrel, the diameter of which is 12 times the nominal diameter (as shown in ANSI B36.10) of the pipe, without developing cracks. When ordered for close coiling (Note 2), the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the outside diameter (as shown in ANSI B36.10) of the pipe, without failure.

11.2 For pipe whose diameter equals or exceeds 10 in. (254 mm) a bend test may be conducted instead of the flattening test. The bend test specimens shall be bent at room temperature through 180° without cracking on the outside of the bent portion. The inside diameter of the bend shall be 1 in. (25.4 mm). Substitution of the bend test for the flattening test shall be subject to the approval of the purchaser.

11.3 For pipe whose diameter exceeds 25 in. (635 mm) and whose diameter to wall thickness ratio is 7.0 or less, the bend test described in 11.2 shall be conducted instead of the flattening test.

NOTE 5 — Diameter to wall thickness ratio = specified outside diameter/nominal wall thickness.

Example: For 28 in. diameter 5.000 in. thick pipe the diameter to wall thickness ratio = 28/5 = 5.6.

12. Flattening Tests

12.1 For pipe over NPS 2 a section of pipe not less than $2\frac{1}{2}$ in. (63.5 mm) in length shall be flattened cold between parallel plates until the opposite walls of the pipe meet. Flattening tests shall be in accordance with Specification A 530/A 530M, except that in the formula used to calculate the "*H*" value, the following "*e*" constants shall be used:

0.08 for Grade A
0.07 for Grades B and C

12.2 When low *D*-to-*t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than 10.

NOTE 6 — The "*H*" values have been calculated for sizes from NPS $2\frac{1}{2}$ to 24, inclusive, and are shown in Table X1.1 of this specification.

13. Hydrostatic Test

13.1 Each length of pipe shall withstand without leakage through the pipe wall, a hydrostatic test, except as provided for in 13.2, 13.3, and 13.4. 98

13.2 When specified by the purchaser, pipe may be tested by the nondestructive electric test method in lieu of the hydrostatic test as shown in Section 14.

13.3 When specified in the order, pipe may be furnished without hydrostatic test and without the NDE in Section 14. In this case, each length so furnished shall include the mandatory marking of the letters "NH."

13.4 When the hydrostatic test and the NDE test are omitted and the lengths marked with the letters "NH," the certification, when required, shall clearly state "Not Hydrostatically Tested," the specification number and material grade, as shown on the certification, shall be followed by the letters "NH."

14. Nondestructive Electric Test

14.1 As an alternative to the hydrostatic test, and when specified by the purchaser, each pipe shall be tested with a nondestructive electric test in accordance with Practice E 213, Practice E 309, or Practice E 570. In this case, each length so furnished shall include the mandatory marking of the letters "NDE." It is the

intent of this test to reject pipe with imperfections which produce test signals equal to or greater than that of the calibration standard.

14.2 When the nondestructive electric test is performed, the lengths shall be marked with the letters "NDE." The certification, when required, shall state "Nondestructive Electric Tested" and shall indicate which of the tests was applied. Also the letters "NDE" shall be appended to the product specification number and material grade shown on the certification.

14.3 The following information is for the benefit of the user of this specification:

98 **14.3.1** The reference standards defined in 14.4 through 14.6 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

14.3.2 The ultrasonic testing can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep defects.

14.3.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type.

14.3.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

14.3.5 The hydrostatic test referred to in Section 13 has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall defects or defects that extend an appreciable distance into the wall without complete penetration.

14.3.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

14.4 For ultrasonic testing, the calibration reference notches shall be, at the option of the producer, any one of the three common notch shapes shown in Practice E 213. The depth of notch shall not exceed 12½% of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

14.5 For eddy current testing, the calibration pipe shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection:

14.5.1 *Drilled Hole* — The calibration pipe shall contain depending upon the pipe diameter three holes spaced 120° apart or four holes spaced 90° apart and sufficiently separated longitudinally to ensure separately distinguishable responses. The holes shall be drilled radially and completely through the pipe wall, care being taken to avoid distortion of the pipe while drilling. Depending upon the pipe diameter the calibration pipe shall contain the following hole:

≤ ½ in.	0.039 in. (1 mm)
> ½ ≤ 1¼ in.	0.055 in. (1.4 mm)
> 1¼ ≤ 2 in.	0.071 in. (1.8 mm)
> 2 ≤ 5 in.	0.087 in. (2.2 mm)
> 5 in.	0.106 in. (2.7 mm)

14.5.2 *Transverse Tangential Notch* — Using a round tool or file with a ¼ in. (6.4 mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12½% of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

14.5.3 *Longitudinal Notch* — A notch 0.031 in. 98 (0.787 mm) or less in width shall be machined in a radial place parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12½% of the specified wall thickness of the tube or 0.004 in. (0.102 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

14.5.4 *Compatibility* — The discontinuity in the calibration pipe shall be compatible with the testing equipment and the method being used.

14.6 For flux leakage testing, the longitudinal calibration reference notches shall be straight-sided notches machined in a radial plane parallel to the pipe axis. For wall thickness under ½ in. (12.7 mm), outside and inside notches shall be used; for wall thickness equal and above ½ in. (12.7 mm), only an outside notch shall be used. Notch depth shall not exceed 12½% of the specified wall thickness, or 0.004 in. (0.102 mm), whichever is greater. Notch length shall not exceed 1 in. (25.4 mm), and the width shall not exceed the depth. Outside diameter and inside diameter notches

shall be located sufficiently apart to allow separation and identification of the signals.

14.7 Pipe producing a signal equal to or greater than the signal produced by the calibration standard shall be subject to rejection. The area producing the signal may be reexamined.

14.7.1 Test signals produced by imperfections which cannot be identified, or produced by cracks or crack-like imperfections shall result in rejection of the pipe, unless it is repaired and retested. To be accepted, the pipe must pass the same specification test to which it was originally subjected, provided that the remaining wall thickness is not decreased below that permitted by this specification. The OD at the point of grinding may be reduced by the amount so reduced.

98 **14.7.2** Test signals produced by visual imperfections such as those listed below may be evaluated in accordance with the provisions of Section 18:

14.7.2.1 Dinges,

14.7.2.2 Straightener marks,

14.7.2.3 Cutting chips,

14.7.2.4 Scratches,

14.7.2.5 Steel die stamps,

14.7.2.6 Stop marks, or

14.7.2.7 Pipe reducer ripple.

14.8 The test methods described in this section may not be capable of inspecting the end portion of pipes. This condition is referred to as "end effect." The length of the end effect shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

15. Nipples

15.1 Nipples shall be cut from pipe of the same dimensions and quality described in this specification.

16. Dimensions, Weight, and Permissible Variations

16.1 *Weight* — The weight of any length of pipe shall not vary more than 10% over and 3.5% under that specified. Unless otherwise agreed upon between the manufacturer and the purchaser, pipe in NPS 4 and smaller may be weighed in convenient lots; pipe larger than NPS 4 shall be weighed separately.

16.2 *Diameter* — Variations in outside diameter shall not exceed those specified in Table 4. 98

16.3 *Thickness* — The minimum wall thickness at any point shall not be more than 12.5% under the nominal wall thickness specified.

NOTE 7 — The minimum wall thicknesses on inspection of some of the available sizes are shown in Table X2.1.

17. Lengths

17.1 Pipe lengths shall be in accordance with the following regular practice:

17.1.1 The lengths required shall be specified in the order, and

17.1.2 No jointers are permitted unless otherwise specified.

17.1.3 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft (4.8 to 6.7 m) with 5% 12 to 16 ft (3.7 to 4.8 m), or in double random lengths with a minimum average of 35 ft (10.7 m) and a minimum length of 22 ft with 5% 16 to 22 ft.

18. Workmanship, Finish and Appearance

18.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to assure compliance with 18.2.

18.2 Surface imperfections that penetrate more than 12½% of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

18.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

18.2.2 Repaired in accordance with the repair welding provisions of 18.6.

18.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

18.2.4 Rejected.

18.3 To provide a workmanlike finish and basis for evaluating conformance with 18.2 the pipe manufacturer shall remove by grinding the following noninjurious imperfections:

18.3.1 Mechanical marks, abrasions (Note 8) and pits, any of which imperfections are deeper than $^1/_{16}$ in. (1.58 mm).

18.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 18.1 to be deeper than 5% of the nominal wall thickness.

18.4 At the purchaser's discretion, pipe shall be subjected to rejection if surface imperfections acceptable under 18.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such a pipe shall be a matter of agreement between the manufacturer and the purchaser.

18.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

18.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

18.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

18.7 The finished pipe shall be reasonably straight.

NOTE 8 — Marks and abrasions are defined as cable marks, dinges, guide marks, roll marks, ball scratches, scores, die marks, etc.

19. End Finish

19.1 The pipe shall be furnished to the following practice, unless otherwise specified.

19.1.1 *NPS 1$^1/_2$ and Smaller* — All walls shall be either plain-end square cut, or plain-end beveled at the option of the manufacturer.

19.1.2 *NPS 2 and Larger* — Walls through extra strong weights, shall be plain end-beveled.

19.1.3 *NPS 2 and Larger* — Walls over extra strong weights, shall be plain-end square cut.

NOTE 9 — Plain-end beveled is defined as plain-end pipe having a bevel angle of 30°, +5° or −0°, as measured from a line drawn perpendicular to the axis of the pipe with a root face of $^1/_{16}$ in. ± $^1/_{32}$ in. (1.5875 ± 0.7938 mm). Other bevel angles may be specified by agreement between the purchaser and the manufacturer.

20. Number of Tests

20.1 The tensile requirements specified in Section 7 shall be determined on one length of pipe from each lot (Note 4) of 400 lengths or fraction thereof of each size under NPS 6, and from each lot of 200 lengths or fraction thereof of each size NPS 6 and over.

20.2 For pipe NPS 2 and under, the bend test specified in 11.1 shall be made on one pipe from each lot of 400 lengths or fraction thereof of each size. The bend test, where used as permitted by 11.2 or required by 11.3, shall be made on one end of 5% of the pipe from each lot. For small lots, at least one pipe shall be tested.

20.3 The flattening test specified in Section 12 shall be made on one length of pipe from each lot of 400 lengths or fraction thereof of each size over NPS 2, up to but not including NPS 6, and from each lot of 200 lengths or fraction thereof, of each size NPS 6 and over.

20.4 Each length of pipe shall be subjected to the hydrostatic test specified in Section 13.

20.5 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

21. Retests

21.1 If the percentage of elongation of any tension test specimen is less than that prescribed in Table 1 and any part of the fracture is more than $^3/_4$ in (19.0 mm) from the center of the gage length of a 2 in., or 50 mm, specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed. If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

21.2 Should a crop end of a finished pipe fail in the flattening test, one retest may be made from the failed end. Pipe may be normalized either before or after the first test, but pipe shall be subjected to only two normalizing treatments.

22. Test Specimens and Test Methods

22.1 On NPS 8 and larger, specimens cut either longitudinally or transversely shall be acceptable for the tension test. On sizes smaller than NPS 8, the longitudinal test only shall be used.

22.2 Test specimens for the bend test specified in Section 11 and for the flattening tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free form burrs, except when made on crop ends.

22.3 Test specimens for the bend test specified in 11.2 and 11.3 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either ½ by ½ in. (12.7 by 12.7 mm) in section or 1 by ½ in. (25.4 by 12.7 mm) in section with the corners rounded to a radius not over 1/16 in. (1.6 mm) and need not exceed 6 in. (152 mm) in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe respectively.

22.4 All routine check tests shall be made at room temperature.

23. Certification

98 **23.1** When test reports are requested, in addition to the requirements of Specification A 530/A 530M, the producer or supplier shall furnish to the purchaser a chemical analysis report for the elements specified in Table 1.

24. Product Marking

98 **24.1** In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include heat number, the information as per Table 5, an additional symbol "S" if the pipe conforms in any case to the supplementary requirements specified in S1 to S5, the length and schedule number, and on pipe sizes larger than NPS 4 the weight shall be given. Length shall be marked in feet and tenths of a foot, or metres to two decimal places, depending on the units to which the material was ordered, or other marking subject to agreement. For sizes NPS 1½, 1¼, 1, and ¾, each length shall be marked as prescribed in Specification A 530/A 530M. These sizes shall be bundled in accordance with standard mill practice and the total bundle footage marked on the bundle tag; individual lengths of pipe need not be marked with footage. For sizes less than NPS ¾, all required markings may be on the bundle tag and shall include the total footage; individual lengths of pipe need not be marked with footage. If not marked on the bundle tag, all required marking shall be on each length.

24.2 When pipe sections are cut into shorter lengths by a subsequent processor for resale as material, the processor shall transfer complete identifying information, including the name or brand of the manufacturer to each unmarked cut length, or to metal tags securely attached to bundles of unmarked small diameter pipe. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

24.3 *Bar Coding* — In addition to the requirements in 24.1 and 24.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used. 98

25. Government Procurement

25.1 When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for the shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Fed. Std. No. 183 if continuous marking is required for military agencies. 98

25.2 *Inspection* — Unless otherwise specified in the contract, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the producer may use his own, or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that the material conforms to the prescribed requirements.

26. Keywords

26.1 carbon steel pipe; seamless steel pipe; steel pipe 98

98

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max[A]	0.25	0.30	0.35
Manganese	0.27–0.93	0.29–1.06	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	0.10	0.10	0.10
Chrome, max[B]	0.40	0.40	0.40
Copper, max[B]	0.40	0.40	0.40
Molybdenum, max[B]	0.15	0.15	0.15
Nickel, max[B]	0.40	0.40	0.40
Vanadium, max[B]	0.08	0.08	0.08

[A] For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to a maximum of 1.35%.

[B] These five elements combined shall not exceed 1%.

98

TABLE 2
TENSILE REQUIREMENTS

	Grade A (Explanatory Note 2)		Grade B		Grade C	
Tensile strength, min, psi (MPa)	48 000 (330)		60 000 (415)		70 000 (485)	
Yield strength, min, psi (MPa)	30 000 (205)		35 000 (240)		40 000 (275)	
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. or 50 mm, min, %:						
Basic minimum elongation transverse strip tests, and for all small sizes tested in full section	35	25	30	16.5	30	16.5
When standard round 2 in. or 50 mm gage length test specimen is used	28 [A,B]	20	22 [A,B]	12	20 [A,B]	12
For longitudinal strip tests						
For transverse strip tests, a deduction for each 1/32 in. (0.8 mm) decrease in wall thickness below 5/16 in. (7.9 mm) from the basic minimum elongation of the following percentage shall be made		1.25 [C]		1.00 [C]		1.00 [C]

[A] The minimum elongation in 2 in. (50.8 mm) shall be determined by the following equation:

$$e = 625\,000A^{0.2}/U^{0.9}$$

where:
e = minimum elongation in 2 in. (50.8 mm), %, rounded to the nearest 0.5%.
A = cross-sectional area of the tension test specimen, in.^{2}, based on specified outside diameter or nominal specimen width and specified wall thickness rounded to the nearest 0.01 in.^{2} If the area thus calculated is greater than 0.75 in.^{2} shall be used, and
U = specified tensile strength, psi.

[B] See Table 3 for minimum elongation values for various size tension specimens and grades.

[C] The following table gives the computed minimum values:

Wall Thickness		Elongation in 2 in. or 50 mm, min, %	
in.	mm	Grade A, Transverse	Grades B and C, Transverse
5/16 (0.312)	7.9	25.00	16.50
9/32 (0.281)	7.1	23.75	15.50
1/4 (0.250)	6.4	22.50	14.50
7/32 (0.219)	5.6	. . .	. . .
3/16 (0.188)	4.8	. . .	. . .
5/32 (0.156)	4.0	. . .	. . .
1/8 (0.125)	3.2	. . .	. . .
3/32 (0.094)	2.4	. . .	. . .
1/16 (0.062)	1.6	. . .	. . .

Note — The above table gives the computed minimum elongation values for each 1/32 in. (0.8 mm) decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

Grade	Direction of Test	Equation
A	Transverse	$E = 40t + 12.50$
B and C	Transverse	$E = 32t + 6.40$

where:
E = elongation in 2 in. or 50 mm, %, and
t = actual thickness of specimen, in.

98

TABLE 3
ELONGATION VALUES

Area, in.^{2} [Note (1)]	Tension Test Specimen Wall Thickness, in. [Note (2)]				Elongation in 2 in. min., Specified Tensile Strength, psi		
	½ in. Specimen	¾ in. Specimen	1 in. Specimen	1½ in. Specimen	Grade A 48 000	Grade B 60 000	Grade C 70 000
≥0.75	≥1.491	≥0.994	≥0.746	≥0.497	36.0	29.5	25.5
0.74	1.470–1.490	0.988–0.993	0.735–0.745	0.490–0.496	36.0	29.5	25.5
0.73	1.451–1.469	0.967–0.979	0.726–0.734	0.484–0.489	36.0	29.5	25.5
0.72	1.430–1.450	0.954–0.966	0.715–0.725	0.477–0.483	36.0	29.5	25.5
0.71	1.411–1.429	0.941–0.953	0.706–0.714	0.471–0.476	35.5	29.0	25.5
0.70	1.390–1.410	0.927–0.940	0.695–0.705	0.464–0.470	35.5	29.0	25.5
0.69	1.371–1.389	0.914–0.926	0.686–0.694	0.457–0.463	35.5	29.0	25.5
0.68	1.350–1.370	0.900–0.913	0.675–0.685	0.450–0.456	35.5	29.0	25.0
0.67	1.331–1.349	0.887–0.899	0.666–0.674	0.444–0.449	35.5	29.0	25.0
0.66	1.310–1.330	0.874–0.886	0.655–0.665	0.437–0.443	35.0	29.0	25.0
0.65	1.291–1.309	0.861–0.873	0.646–0.654	0.431–0.436	35.0	28.5	25.0
0.64	1.270–1.290	0.847–0.860	0.635–0.645	0.424–0.430	35.0	28.5	25.0
0.63	1.251–1.269	0.834–0.846	0.626–0.634	0.417–0.423	35.0	28.5	25.0
0.62	1.230–1.250	0.820–0.833	0.615–0.625	0.410–0.416	35.0	28.5	25.0
0.61	1.211–1.229	0.807–0.819	0.606–0.614	0.404–0.409	34.5	28.5	24.5
0.60	1.190–1.210	0.794–0.806	0.595–0.605	0.397–0.403	34.5	28.5	24.5
0.59	1.171–1.189	0.781–0.793	0.586–0.594	0.391–0.396	34.5	28.0	24.5
0.58	1.150–1.170	0.767–0.780	0.575–0.585	0.384–0.390	34.5	28.0	24.5
0.57	1.131–1.149	0.754–0.766	0.566–0.574	0.377–0.383	34.0	28.0	24.5
0.56	1.110–1.130	0.740–0.753	0.555–0.565	0.370–0.376	34.0	28.0	24.5
0.55	1.091–1.109	0.727–0.739	0.546–0.554	0.364–0.369	34.0	28.0	24.9
0.54	1.070–1.090	0.714–0.726	0.535–0.545	0.357–0.363	34.0	27.5	24.0
0.53	1.051–1.069	0.701–0.713	0.526–0.534	0.351–0.356	33.5	27.5	24.0
0.52	1.030–1.050	0.687–0.700	0.515–0.525	0.344–0.350	33.5	27.5	24.0
0.51	1.011–1.029	0.674–0.686	0.506–0.514	0.337–0.343	33.5	27.5	24.0
0.50	0.990–1.010	0.660–0.673	0.495–0.505	0.330–0.336	33.5	27.0	23.5
0.49	0.971–0.989	0.647–0.659	0.486–0.494	0.324–0.329	33.0	27.0	23.5
0.48	0.950–0.970	0.634–0.646	0.475–0.485	0.317–0.323	33.0	27.0	23.5
0.47	0.931–0.949	0.621–0.633	0.466–0.474	0.311–0.316	33.0	27.0	23.5
0.46	0.910–0.930	0.607–0.620	0.455–0.465	0.304–0.310	33.0	27.0	23.5
0.45	0.891–0.909	0.594–0.606	0.446–0.454	0.297–0.303	32.5	26.5	23.0
0.44	0.870–0.890	0.580–0.593	0.435–0.445	0.290–0.296	32.5	26.5	23.0
0.43	0.851–0.869	0.567–0.579	0.426–0.434	0.284–0.289	32.5	26.5	23.0
0.42	0.830–0.850	0.554–0.566	0.415–0.425	0.277–0.283	32.0	26.5	23.0
0.41	0.811–0.829	0.541–0.553	0.406–0.414	0.271–0.276	32.0	26.0	23.0
0.40	0.790–0.810	0.527–0.540	0.395–0.405	0.264–0.270	32.0	26.0	22.5
0.39	0.771–0.789	0.514–0.526	0.386–0.394	0.257–0.263	31.5	26.0	22.5
0.38	0.750–0.770	0.500–0.513	0.375–0.385	0.250–0.256	31.5	26.0	22.5
0.37	0.731–0.749	0.487–0.499	0.366–0.374	0.244–0.249	31.5	25.5	22.5
0.36	0.710–0.730	0.474–0.486	0.355–0.365	0.237–0.243	31.0	25.5	22.0

TABLE 3 (CONT'D)
ELONGATION VALUES

Area, in.^{2} [Note (1)]	Tension Test Specimen Wall Thickness, in. [Note (2)]				Elongation in 2 in. min., Specified Tensile Strength, psi		
					Grade A	Grade B	Grade C
	$\frac{1}{2}$ in. Specimen	$\frac{3}{4}$ in. Specimen	1 in. Specimen	$1\frac{1}{2}$ in. Specimen	48 000	60 000	70 000
0.35	0.691–0.709	0.461–0.473	0.346–0.354	0.231–0.236	31.0	25.5	22.0
0.34	0.670–0.690	0.447–0.460	0.335–0.345	0.224–0.230	31.0	25.0	22.0
0.33	0.651–0.669	0.434–0.446	0.326–0.334	0.217–0.223	30.5	25.0	22.0
0.32	0.630–0.650	0.420–0.433	0.315–0.325	0.210–0.216	30.5	25.0	21.5
0.31	0.611–0.629	0.407–0.419	0.306–0.314	0.204–0.209	30.5	25.0	21.5
0.30	0.590–0.610	0.394–0.406	0.295–0.305	0.197–0.203	30.0	24.5	21.5
0.29	0.571–0.589	0.381–0.393	0.286–0.294	0.191–0.196	30.0	24.5	21.5
0.28	0.550–0.570	0.367–0.380	0.275–0.285	0.184–0.190	29.5	24.5	21.0
0.27	0.531–0.549	0.354–0.366	0.266–0.274	0.177–0.183	29.5	24.0	21.0
0.26	0.510–0.530	0.340–0.353	0.255–0.265	0.170–0.176	29.0	24.0	21.0
0.25	0.491–0.509	0.327–0.339	0.246–0.254	0.164–0.169	29.0	23.5	20.5
0.24	0.470–0.490	0.314–0.326	0.235–0.245	0.157–0.163	29.0	23.5	20.5
0.23	0.451–0.469	0.301–0.313	0.226–0.234	0.151–0.156	28.5	23.5	20.5
0.22	0.430–0.450	0.287–0.300	0.215–0.225	0.144–0.150	28.5	23.0	20.0
0.21	0.411–0.429	0.274–0.286	0.206–0.214	0.137–0.143	28.0	23.0	20.0
0.20	0.390–0.410	0.260–0.273	0.195–0.205	0.130–0.136	27.5	22.5	19.5
0.19	0.371–0.389	0.247–0.259	0.186–0.194	0.124–0.129	27.5	22.5	19.5
0.18	0.350–0.370	0.234–0.246	0.175–0.185	0.117–0.123	27.0	22.0	19.5
0.17	0.331–0.349	0.221–0.233	0.166–0.174	0.111–0.116	27.0	22.0	19.0
0.16	0.310–0.330	0.207–0.220	0.155–0.165	0.104–0.110	26.5	21.5	19.0
0.15	0.291–0.309	0.194–0.206	0.146–0.154	0.097–0.103	26.0	21.5	18.5
0.14	0.270–0.290	0.180–0.193	0.135–0.145	0.091–0.096	26.0	21.0	18.5
0.13	0.251–0.269	0.167–0.179	0.126–0.134	0.084–0.090	25.5	21.0	18.0
0.12	0.230–0.250	0.154–0.166	0.115–0.125	0.077–0.083	25.0	20.5	18.0
0.11	0.211–0.229	0.141–0.153	0.106–0.114	0.071–0.076	24.5	20.0	17.5
0.10	0.190–0.210	0.127–0.140	0.095–0.105	0.064–0.070	24.0	19.5	17.0
0.09	0.171–0.189	0.114–0.126	0.086–0.094	0.057–0.063	23.5	19.5	17.0
0.08	0.150–0.170	0.100–0.113	0.075–0.085	0.050–0.056	23.0	19.0	16.5
0.07	0.131–0.149	0.087–0.099	0.066–0.074	0.044–0.049	22.5	18.5	16.0
0.06	0.110–0.130	0.074–0.086	0.055–0.065	0.037–0.043	22.0	18.0	15.5
0.05	0.091–0.109	0.061–0.073	0.046–0.054	0.031–0.036	21.0	17.0	15.0
0.04	0.070–0.090	0.047–0.060	0.035–0.045	0.024–0.030	20.0	16.5	14.5
0.03	0.051–0.069	0.034–0.046	0.026–0.034	0.017–0.023	19.0	15.5	13.5
0.02	0.030–0.050	0.020–0.033	0.015–0.025	0.010–0.016	17.5	14.5	12.5
≤0.01	≤0.029	≤0.019	≤0.014	≤0.009	15.0	12.5	11.0

NOTES:
(1) 1 in.^{2} = 645.16 mm^2.
(2) 1 in. = 25.4 mm.

98

TABLE 4
VARIATIONS IN OUTSIDE DIAMETER

	Permissible Variations in Outside Diameter			
	Over		Under	
NPS Designator	in.	mm	in.	mm
1/8 to 1 1/2, incl	1/64 (0.015)	0.40	1/64 (0.015)	0.40
Over 1 1/2 to 4, incl	1/32 (0.031)	0.79	1/32 (0.031)	0.79
Over 4 to 8, incl	1/16 (0.062)	1.59	1/32 (0.031)	0.79
Over 8 to 18, incl	3/32 (0.093)	2.38	1/32 (0.031)	0.79
Over 18 to 26, incl	1/8 (0.125)	3.18	1/32 (0.031)	0.79
Over 26 to 34, incl	5/32 (0.156)	3.97	1/32 (0.031)	0.79
Over 34 to 48, incl	3/16 (0.187)	4.76	1/32 (0.031)	0.79

98

TABLE 5
MARKING

Hydro	NDE	Marking
Yes	No	Test Pressure
No	Yes	NDE
No	No	NH
Yes	Yes	Test Pressure/NDE

SUPPLEMENTARY REQUIREMENTS 98

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Test

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Metal Structure and Etching Test

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate sections of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonable uniform material free form injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Carbon Equivalent

S5.1 The steel shall conform to a carbon equivalent (CE) of 0.50 maximum as determined by the following formula:

$$CE = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Ni + \%Cu}{15}$$

S5.2 A lower CE maximum may be agreed upon between the purchaser and the producer.

S5.3 The CE shall be reported on the test report.

S6. Heat Treated Test Specimens

S6.1 At the request of the purchaser, one tensile test shall be performed by the manufacturer on a test specimen from each heat of steel furnished which has been either stress relieved at 1250°F or normalized at 1650°F, as specified by the purchaser. Other stress relief or annealing temperatures, as appropriate to the analysis, may be specified by agreement between the purchaser and the manufacturer. The results of this test shall meet the requirements of Table 2. 98

S7. Internal Cleanliness — Government Orders

S7.1 The internal surface of hot finished ferritic steel pipe and tube shall be manufactured to a free of scale condition equivalent to the visual standard listed in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

APPENDIX

(Nonmandatory Information)

X1. CALCULATED H VALUES FOR SEAMLESS PIPE

98 **X1.1** Table XI.1 and X1.2 lists values for *H* to be used for the test of Section 12.

TABLE X1.1
CALCULATED "*H*" VALUES FOR SEAMLESS PIPE

Inch-Pound Units

NPS Designator	Outside Diameter, in.	Wall Thickness, in.	Schedule Number	Distance, in inches, Between Plates "*H*" by Equation: $H = -\frac{(1+e)t}{e+t/D}$ Grade A	Grades B & C
2½	2.875	0.203	40	1.456	1.545
		0.276	80	1.694	1.779
		0.375	160	1.925	2.002
3	3.500	0.216	40	1.646	1.755
		0.300	80	1.955	2.062
		0.438	160	2.306	2.398
3½	4.000	0.226	40	1.788	1.912
		0.318	80	2.153	2.276
4	4.500	0.237	40	1.929	2.067
		0.337	80	2.350	2.489
		0.438	120	2.687	2.818
		0.531	160	2.896	3.022
5	5.563	0.258	40	2.205	2.372
		0.375	80	2.747	2.920
		0.500	120	3.179	3.346
		0.625	160	3.509	3.667
6	6.625	2.80	40	2.473	2.669
		0.432	80	3.213	3.419
		0.562	120	3.682	3.884
		0.719	160	4.116	4.307
8	8.625	0.250	20	2.477	2.702
		0.277	30	2.668	2.902
		0.322	40	2.964	3.210
		0.406	60	3.451	3.711
		0.500	80	3.914	4.181
		0.593	100	4.305	4.573
		0.719	120	4.750	5.013
		0.812	140	5.036	5.293
		0.906	160	5.288	5.538
10	10.750	0.250	20	2.615	2.868
		0.307	30	3.054	3.333
		0.365	40	3.459	3.757
		0.500	60	4.268	4.592
		0.593	80	4.738	5.070
		0.719	100	5.320	5.621
		0.843	120	5.747	6.077
		1.000	140	6.242	6.564
		1.125	160	6.580	6.892
12	12.750	0.250	20	2.711	2.985
		0.330	30	3.366	3.683
		0.406	40	3.921	4.266
		0.562	60	4.892	5.271
		0.687	80	5.542	5.934
		0.843	100	6.231	6.627
		1.000	120	6.817	7.209
		1.125	140	7.222	7.607
		1.312	160	7.747	8.119
14	14.000	0.250	10	2.759	3.045
		0.312	20	3.294	3.617
		0.375	30	3.792	4.146
		0.438	40	4.669	5.125
		0.593	60	5.234	5.647
		0.750	80	6.064	6.494
		0.937	100	6.887	7.322
		1.093	120	7.479	7.902
		1.250	140	7.974	8.397
		1.406	160	8.416	8.827
16	16.000	0.250	10	2.284	3.124
		0.312	20	3.387	3.730
		0.375	30	3.915	4.294
		0.500	40	4.854	5.284
		0.656	60	5.855	6.324
		0.843	80	6.861	7.352
		1.031	100	7.709	8.206
		1.218	120	8.426	8.919
		1.438	140	9.141	9.625
		1.593	160	9.579	10.050
18	18.000	0.250	10	2.876	3.189
		0.312	20	3.462	3.823
		0.438	30	4.535	4.963
		0.562	40	5.457	5.941
		0.750	60	6.656	7.185
		0.937	80	7.663	8.214
		1.156	100	8.657	9.216
		1.375	120	9.495	10.043
		1.562	140	10.115	10.660
		1.781	160	10.665	11.198
20	20.000	0.250	10	2.919	3.242
		0.375	20	4.101	4.521
		0.500	30	5.143	5.632
		0.593	40	5.841	6.367
		0.812	60	7.272	7.856
		1.031	80	8.464	9.072
		1.281	100	9.601	10.221
		1.500	120	10.452	11.069
		1.750	140	11.284	11.889
		1.968	160	11.913	12.504
24	24.000	0.250	10	2.986	3.326
		0.375	20	4.236	4.686
		0.562	30	5.869	6.437
		0.687	40	6.831	7.454
		0.968	60	8.690	9.390
		1.218	80	10.061	10.793
		1.531	100	11.449	12.244
		1.812	120	12.585	13.332
		2.062	140	13.424	14.150
		2.343	160	14.248	14.958

98

TABLE X1.2
CALCULATED "H" VALUES FOR SEAMLESS PIPE

SI Units

NPS Designator	Outside Diameter, mm	Wall Thickness, mm	Schedule Number	Distance, in mm, Between Plates "H" by Equation: $H = \frac{(1 + e)t}{e + t/D}$ Grade A	Grades B & C
2½	73.0	5.16	40	37.0	39.2
		7.01	80	43.0	45.2
		9.52	160	48.9	50.8
3	88.9	5.49	40	41.8	44.6
		7.62	80	49.6	52.4
		11.13	160	58.6	60.9
3½	101.6	5.74	40	45.4	48.6
		8.08	80	54.7	57.8
4	114.3	6.02	40	49.0	52.5
		8.56	80	59.7	63.2
		11.13	120	67.0	71.6
		13.49	160	73.6	76.8
5	141.3	6.55	40	56.0	60.2
		9.52	80	69.8	74.2
		12.70	120	80.8	85.0
		15.88	160	89.1	93.1
6	168.3	7.11	40	62.8	67.8
		10.97	80	81.6	86.8
		14.27	120	93.5	98.6
		18.24	160	104.6	109.4
8	219.1	6.35	20	63.0	68.6
		7.04	30	67.8	73.7
		8.18	40	75.3	81.5
		10.31	60	87.7	94.3
		12.70	80	99.4	106.2
		15.06	100	109.4	116.2
		18.24	120	120.6	127.3
		20.62	140	127.9	134.4
		23.01	160	134.3	140.7
10	273.0	6.35	20	66.4	72.8
		7.80	30	77.6	84.7
		9.27	40	87.9	95.4
		12.70	60	108.4	116.6
		15.06	80	120.4	128.8
		18.24	100	135.1	142.8
		21.41	120	146.0	154.4
		25.40	140	158.6	166.7
		28.58	160	167.1	175.1
12	323.8	6.35	20	68.9	75.8
		8.38	30	85.5	93.6
		10.31	40	99.6	108.4
		14.27	60	124.3	133.9
		17.35	80	140.8	150.7
		21.41	100	158.3	168.3
		25.40	120	173.2	183.1
		28.58	140	183.4	193.2
		33.32	160	196.8	206.2
14	355.6	6.35	10	70.1	77.3
		7.92	20	83.7	91.8
		9.52	30	96.3	105.3
		11.13	40	118.6	130.2
		15.06	60	132.9	143.4
		19.05	80	154.0	165.0
		23.80	100	174.9	186.0
		27.76	120	190.0	200.7
		31.75	140	202.5	213.3
		35.71	160	213.8	224.2
16	406.4	6.35	10	71.7	79.4
		7.92	20	89.0	94.7
		9.52	30	99.4	109.1
		12.70	40	123.3	143.2
		16.66	60	148.7	160.6
		21.41	80	174.3	186.7
		26.19	100	195.8	208.4
		30.94	120	214.0	226.6
		36.53	140	232.2	244.5
		40.46	160	243.3	255.3
18	457.2	6.35	10	73.0	81.0
		7.92	20	87.9	97.1
		11.13	30	115.2	126.1
		14.27	40	139.5	150.9
		19.05	60	169.1	182.5
		23.80	80	194.6	208.6
		29.36	100	219.9	234.1
		34.92	120	241.2	255.1
		39.67	140	256.9	270.7
		45.24	160	270.9	284.4
20	508.0	6.35	10	74.1	82.4
		9.52	20	104.2	114.8
		12.70	30	130.6	143.0
		15.06	40	148.4	161.7
		20.62	60	184.7	199.5
		26.19	80	215.0	230.4
		32.54	100	243.9	259.6
		38.10	120	265.5	281.2
		44.45	140	286.6	302.0
		49.99	160	302.6	317.6
24	609.6	6.35	10	75.8	84.5
		9.52	20	107.6	119.0
		14.27	30	149.1	163.5
		17.35	40	173.5	189.3
		24.59	60	220.7	238.5
		30.94	80	255.6	274.1
		38.89	100	290.8	311.0
		46.02	120	319.7	338.6
		52.37	140	341.0	359.4
		59.51	160	361.9	379.9

X2. MINIMUM WALL THICKNESSES

X2.1 Table X2.1 lists minimum wall thicknesses for nominal pipe wall thickness.

98

TABLE X2.1
MINIMUM WALL THICKNESSES ON INSPECTION FOR NOMINAL (AVERAGE) PIPE WALL THICKNESS

Note 1 — The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:
t_n = nominal (average) wall thickness, in. and
t_m = minimum wall thickness, in.

The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped, in accordance with Practice E 29.

Note 2 — This table covers some wall thicknesses associated with standard pipe sizes but is not meant to imply that these are the only thicknesses obtainable under this specification.

Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)	
in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.068	1.73	0.060	1.52	0.281	7.14	0.246	6.25	0.864	21.94	0.756	19.20
0.083	2.11	0.073	1.85	0.294	7.47	0.257	6.53	0.875	22.22	0.766	19.46
0.088	2.24	0.077	1.96	0.300	7.62	0.262	6.65	0.906	23.01	0.793	20.14
0.091	2.31	0.080	2.03	0.307	7.80	0.269	6.83	0.938	23.82	0.821	20.85
0.095	2.41	0.083	2.11	0.308	7.82	0.270	6.86	0.968	24.59	0.847	21.51
0.109	2.77	0.095	2.41	0.312	7.92	0.273	6.93	1.000	25.40	0.875	22.22
0.113	2.87	0.099	2.51	0.318	8.07	0.278	7.06	1.031	26.19	0.902	22.91
0.119	3.02	0.104	2.64	0.322	8.18	0.282	7.16	1.062	26.97	0.929	23.60
0.125	3.18	0.109	2.77	0.330	8.38	0.289	7.34	1.094	27.79	0.957	24.31
0.126	3.20	0.110	2.79	0.337	8.56	0.295	7.49	1.125	28.58	0.984	24.99
0.133	3.38	0.116	2.95	0.344	8.74	0.301	7.64	1.156	29.36	1.012	25.70
0.140	3.56	0.122	3.10	0.358	9.09	0.313	7.95	1.219	30.96	1.066	27.08
0.141	3.58	0.123	3.12	0.365	9.27	0.319	8.10	1.250	31.75	1.094	27.79
0.145	3.68	0.127	3.23	0.375	9.52	0.328	8.33	1.281	32.54	1.121	28.47
0.147	3.73	0.129	3.28	0.382	9.70	0.334	8.48	1.312	33.32	1.148	29.16
0.154	3.91	0.135	3.43	0.400	10.16	0.350	8.89	1.375	34.92	1.203	30.56
0.156	3.96	0.136	3.45	0.406	10.31	0.355	9.02	1.406	35.71	1.230	31.24
0.172	4.37	0.150	3.81	0.432	10.97	0.378	9.60	1.438	36.53	1.258	31.95
0.179	4.55	0.157	3.99	0.436	11.07	0.382	9.70	1.500	38.10	1.312	33.32
0.188	4.78	0.164	4.17	0.438	11.12	0.383	9.73	1.531	38.89	1.340	34.04
0.191	4.85	0.167	4.24	0.469	11.91	0.410	10.41	1.562	39.67	1.367	34.72
0.200	5.08	0.175	4.44	0.500	12.70	0.438	11.13	1.594	40.49	1.395	35.43
0.203	5.16	0.178	4.52	0.531	13.49	0.465	11.81	1.635	41.53	1.431	36.35
0.210	5.33	0.184	4.67	0.552	14.02	0.483	12.27	1.750	44.45	1.531	38.89
0.216	5.49	0.189	4.80	0.562	14.27	0.492	12.50	1.781	45.24	1.558	39.57
0.218	5.54	0.191	4.85	0.594	15.09	0.520	13.21	1.812	46.02	1.586	40.28
0.219	5.56	0.192	4.88	0.600	15.24	0.525	13.34	1.875	47.62	1.641	41.68
0.226	5.74	0.198	5.03	0.625	15.88	0.547	13.89	1.969	50.01	1.723	43.76
0.237	6.02	0.207	5.26	0.656	16.66	0.574	14.58	2.000	50.80	1.750	44.45
0.250	6.35	0.219	5.56	0.674	17.12	0.590	14.99	2.062	52.37	1.804	45.82
0.258	6.55	0.226	5.74	0.688	17.48	0.602	15.29	2.125	53.98	1.859	47.22
0.276	7.01	0.242	6.15	0.719	18.26	0.629	15.98	2.200	55.88	1.925	48.90
0.277	7.04	0.242	6.15	0.750	19.05	0.656	16.66	2.344	59.54	2.051	52.10
0.279	7.09	0.244	6.19	0.812	20.62	0.710	18.03	2.500	63.50	2.188	55.58
0.280	7.11	0.245	6.22	0.844	21.44	0.739	18.77				

SPECIFICATION FOR PIPE, STEEL, ELECTRIC-FUSION (ARC)-WELDED (SIZES NPS 16 AND OVER)

SA-134

(Identical with ASTM Specification A 134-93 except that the following additional requirement applies)

All products furnished under this SA specification are intended for application under the rules for ASME Section III for Class III piping. Furnishing of such products is limited to manufacturers who hold the appropriate ASME Code Symbol Stamp. Weld procedures, welder, and welding machine operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX. The product shall meet all applicable requirements of Class III Piping including those requirements pertaining to heat treatment and butt welds. *The plate used to fabricate the pipe shall conform to SA-283 or SA-285.* Authorized inspection at the point of manufacture, and application of the appropriate Code Symbol Stamp is required.

The applicable ASME Partial Data Report Form, signed by an Authorized Inspector, and a certified mill test report shall be furnished for each lot of pipe. The term "lot" applies to all pipe of the same mill heat of material and wall thickness which is heat treated in one furnace charge. For pipe which is not heat treated, or which is heat treated in a continuous furnace, a lot shall consist of each 200 ft (61 m) or fraction thereof of all pipe of the same mill heat of material and wall thickness, subjected to the same heat treatment. For pipe which is heat treated in a batch-type furnace which is automatically controlled within a 50°F range and equipped with recording pyrometers so that the heating records are available, a lot may be defined the same as for continuous furnaces. Each length of pipe shall be marked in such a manner as to identify each such piece with the lot and the certified mill test report.

1. Scope

1.1 This specification covers electric-fusion (arc)-welded straight seam or spiral seam steel pipe NPS 16 and over in diameter (inside or outside as specified by purchaser), with wall thicknesses up to $\frac{3}{4}$ in. (19.0 mm), inclusive. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

NOTE 1 — Acceptability for many services may be controlled by codes or standards such as those published by the American National Standards Institute and American Society of Mechanical Engineers.

NOTE 2 — For testing methods not specifically covered in this specification, reference can be made to Test Methods and Definitions A 370, with particular reference to Annex A2 on Steel Tubular Products.

NOTE 3 — A comprehensive listing of standardized pipe dimensions is contained in ANSI B36.10.

1.2 The values stated in inch-pound units are to be regarded as the standard.

NOTE 4 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.3 The following precautionary caveat pertains specifically to Section 5 of this specification. *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 36/A 36M Specification for Structural Steel

A 283/A 283M Specification for Low and Intermediate Tensile Strength Carbon Steel Plates
A 285/A 285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 570/A 570M Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Quality

2.2 *ASME Boiler and Pressure Vessel Code:*
Section IX Welding Qualifications

2.3 *American National Standards Institute Standard:*
B16.25 Buttwelding Ends
B36.10 Welded and Seamless Wrought Steel Pipe

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (electric-fusion (arc)-welded pipe),

3.1.3 Grade (Section 4),

3.1.4 Size (inside or outside diameter and nominal wall thickness),

3.1.5 Length (specified or random),

3.1.6 Specific straightness requirements (see 12.3),

3.1.7 End finish (Section 14),

3.1.8 Hydrostatic test pressure (Section 8),

3.1.9 ASTM designation, and

3.1.10 End use of material.

4. Material

4.1 The steel from which the pipe is made shall conform to Specifications A 283/A 283M, A 285/A 285M, A 570 or A 36/A 36M or to other ASTM specifications for equally suitable weldable material, as specified: For purposes of marking and certification, when required, the pipe grade of material shall be established by the A xxx plate specification designation and plate grade, when applicable.

5. Manufacture

5.1 The longitudinal edges of the steel shall be shaped to give the most satisfactory results by the particular welding process employed. The steel shall then be properly formed and may be tacked preparatory to welding. The weld shall be made by automatic means (except tack welds) and shall be of reasonably uniform width and height for the entire length of the pipe. By agreement between the purchaser and the manufacturer, manual welding by qualified procedure and welders may be used as an equal alternate under this specification.

5.2 All longitudinal seams, spiral seams, and shop girth seams shall be butt-welded.

6. Qualification of Welding Procedure

6.1 The welding procedure shall be qualified in accordance with the American Welding Society Standard Qualification Procedure or ASME Section IX of the Boiler and Pressure Vessel Code as agreed to between the manufacturer and the purchaser using the tests and test values specified in 6.2 and 6.3. Thicknesses less than $\frac{3}{8}$ in. (10 mm) shall be qualified for each wall thickness of pipe manufactured. Thicknesses $\frac{3}{8}$ to $\frac{3}{4}$ in. (10 mm to 19.0 mm), inclusive, shall be qualified in $\frac{3}{8}$ in. (10 mm) thickness.

6.2 Two reduced-section tension specimens (transverse weld) made in accordance with Fig. 21 of Test Methods and Definitions A 370, with the weld reinforcement removed, shall show a tensile strength not less than 100% of the minimum specified tensile strength of the base material used.

6.3 Two face-bend test specimens shall be prepared in accordance with Fig. 29 (a) of Test Methods and Definitions A 370 and shall withstand being bent 180° in a jig substantially in accordance with Fig. 30 of Test Methods and Definitions A 370. The bend test shall be acceptable if no cracks or other defects exceeding $\frac{1}{8}$ in. (3.2 mm) in any direction be present in the weld metal or between the weld and the pipe metal after bending. Cracks that originate along the edges of the specimens during testing and that are less than $\frac{1}{4}$ in. (6.3 mm) in any direction, shall not be considered.

7. Tensile Properties of Production Welds

7.1 Reduced-section tension test specimens required in Section 9 taken perpendicularly across the weld with the weld reinforcement removed, shall show a tensile

strength not less than 95% of the specified minimum strength of the steel. At the manufacturer's option, the test may be made without removing the weld reinforcement, in which case the tensile strength shall be not less than the specified minimum tensile strength for the grade of steel used.

8. Hydrostatic Test (Note 5)

8.1 Each length of pipe shall be tested by the manufacturer to a hydrostatic pressure that will produce in the pipe wall a stress of 60% of the specified minimum yield point of the steel used at room temperature. The pressure shall be determined by the following equation:

$$P = 2St/D$$

where:

P = minimum hydrostatic test pressure, psi (Note 6) (not to exceed 2800 psi (19 MPa)),
S = 0.60 times the minimum specified yield point of the steel used, psi (MPa),
t = specified wall thickness, in. (mm), and
D = specified outside diameter, in. (mm).

NOTE 5 — A hydrostatic sizing operation is not to be considered a hydrostatic test or a substitute for it.

NOTE 6 — When the diameter and wall thickness of pipe are such that the capacity limits of testing equipment are exceeded by these requirements, the test pressure may be reduced by agreement between the purchaser and the manufacturer.

8.2 Test pressure shall be held for not less than 5 s, or for a longer time as agreed upon between the purchaser and the manufacturer.

NOTE 7 — When agreed upon between the purchaser and the manufacturer and so stated on the order, pipe may be tested to one and one half times the specified working pressure, except that the maximum test pressure shall not exceed 2800 psi (19 MPa) nor shall the maximum fiber stress exceed 85% of specified minimum yield point of steel or to a fiber stress that does not exceed 85% of the specified minimum yield point of the steel or 2800 psi (19 MPa) test pressure.

8.3 When specified in the order, pipe may be furnished without hydrostatic testing and each length so furnished shall include the mandatory marking of the letters "NH." Additionally, the certification, when required, shall state "Not Hydrostatically Tested" and the specification number and material grade, as shown on the certification, shall be followed by the letters "NH."

9. Test Specimens of Production Welds

9.1 The weld-test specimens for the reduced-section tension test shall be taken perpendicularly across the weld and from the end of the pipe or alternatively, from flat test pieces of material conforming to the requirements in the specifications used in the manufacture of the pipe. The alternative weld-test specimens shall be welded with the same procedure and by the same operator and equipment, and in sequence with the welding of the longitudinal joints in the pipe. The test pieces shall have the weld approximately in the middle of the specimen. The specimens shall be straightened cold, and shall be tested at room temperature.

9.2 Reduced-section tension-test specimens shall be prepared in accordance with Fig. 21 of Test Methods and Definitions A 370.

10. Number of Production Weld Tests

10.1 One weld test specimen specified in Section 9 shall be made from each lot of 3000 ft (900 m) of pipe or fraction thereof of each size and wall thickness.

10.2 If any test specimen shows defective machining or develops flaws not associated with the welding, it may be discarded and another specimen substituted.

10.3 Each length of pipe shall be subjected to the hydrostatic test specified in Section 8, unless otherwise specified in 8.3.

11. Retests

11.1 If any specimen tested in accordance with Section 7 fails to meet the requirements, retests of two additional specimens from the same lot of pipe shall be made, each of which shall meet the requirements specified. If any of the retests fail to conform to the requirements, test specimens may be taken from each untested pipe length at the manufacturer's option. Each specimen shall meet the requirements specified, or that pipe shall be rejected.

12. Permissible Variations in Weights and Dimensions

12.1 *Thickness and Weight* — The wall thickness and weight for welded pipe under this specification shall be governed by the requirements of the specifications to which the steel was ordered.

12.2 *Circumference* — The outside circumference of the pipe shall not vary more than ±0.5% from the nominal outside circumference based upon the diameter specified, except that the circumference at ends shall be sized, if necessary, to meet the requirements of Section 14.

12.3 *Straightness* — Finished pipe shall be commercially straight. When specific straightness requirements are desired, the order should so state, and the tolerances shall be a matter of agreement between the purchaser and the manufacturer.

12.4 *Ovality — Out-of-roundness* — The difference between major and minor outside diameter shall not exceed 1%. Closer tolerances may be established by agreement between the manufacturer and the purchaser. Where the *D/T* (outside diameter/wall thickness) is over 120, internal bracing should be utilized to achieve sizing of ends and ovality shall be by agreement between the manufacturer and the purchaser.

13. Lengths

13.1 Pipe lengths shall be supplied in accordance with the following regular practice:

13.1.1 The lengths shall be specified on the order with a tolerance of ±½ in. (13 mm), except that the shorter lengths from which test coupons have been cut may also be shipped.

13.1.2 When random lengths are specified, pipe shall be furnished in lengths having a minimum average of 29 ft (9 m) with a minimum length of 20 ft (6 m), but not more than 5% may be under 25 ft (8 m).

13.2 Pipe lengths containing circumferentially welded joints (Note 8) shall be permitted by agreement between the manufacturer and the purchaser. Tests of these welded joints shall be made in accordance with the procedure tests specified in Section 6 and the production weld tests specified in Section 7. The number of production weld tests shall be one per each lot of 100 joints or fraction thereof, but not less than one for each welder or welding operator.

NOTE 8 — Joints are defined for the purpose of this specification as a circumferential welded seam lying in one plane, used to join lengths of straight pipe.

14. Ends

14.1 Pipe shall be furnished with a plain right-angle cut or with bevel ends as specified. All burrs at the ends of pipe shall be removed.

14.1.1 Unless otherwise specified, pipe with beveled ends shall meet the requirements of ANSI B16.25.

14.2 Unless otherwise specified, the outside circumference of pipe ends for a distance of not less than 4 in. (100 mm) shall not vary more than ±60% of the nominal wall thickness of the pipe from the nominal outside circumference based on the diameter specified, except that the tolerance shall not be less than ±$^{3}/_{16}$ in. (5 mm).

14.3 By agreement between the manufacturer and the purchaser the ends of the pipe may be sized within agreed-upon tolerances if necessary to meet the requirements of special installations.

15. Finish

15.1 *Repair by Welding* — The welding of injurious defects in the pipe wall, provided their depth does not exceed one third the specified wall thickness, will be permitted. Defects in the welds, such as sweats or leaks, shall be repaired or the piece rejected at the option of the manufacturer. Repairs of this nature shall be made by completely removing the defect, cleaning the cavity, and then welding.

15.2 All repaired pipe shall be tested hydrostatically in accordance with Section 8, unless otherwise specified in 8.3.

16. Inspection

16.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment and unless otherwise specified, shall be so conducted as not to interfere unnecessarily with the operation of the works. If agreed upon, the manufacturer shall notify the purchaser in time so that he may have his inspector present to witness any part of the manufacture or tests that may be desired. The certification shall include reference

to this specification and pipe grade (ASTM plate specification designation and plate grade, when applicable).

16.2 *Certification* — Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the chemical and tensile tests shall be furnished. When hydrostatic test is omitted, the certificate shall include the letters "NH. "

17. Rejection

17.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected, and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

17.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement between the purchaser and the manufacturer.

18. Certification

18.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, including year date, together with a report of the chemical and tensile tests shall be furnished. The pipe grade shall be identified by the plate specification designation (year date not required) and the plate grade (where applicable).

19. Product Marking

19.1 Each section of pipe shall be marked with the manufacturer's distinguishing marking, this specification number and the pipe grade. The marking need not include the year date of the pipe or plate specification.

19.2 *Bar Coding* — In addition to the requirements in 19.1, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

20. Protective Coating

20.1 If agreed upon between the purchaser and the manufacturer, the pipe shall be given a protective coating of the kind and in the manner specified by the purchaser.

SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED STEEL PIPE

SA-135

(Identical with ASTM Specification A 135-96) 98

1. Scope

98 **1.1** This specification covers two grades of electric-resistance-welded steel pipe in NPS 2 to NPS 30 inclusive, with nominal (average) wall thickness up to 0.500 in. (12.70 mm), inclusive, and in nominal sizes $\frac{3}{4}$ to 5 in. (19 to 127 mm) inclusive with nominal (average) wall thickness 0.083 in. (2.11 mm) to 0.134 in. (3.40 mm), depending on size. Pipe having other dimensions (Note 1) may be furnished provided such pipe complies with all other requirements of this specification. The pipe is intended for conveying gas, vapor, water or other liquid; and only Grade A is adapted for flanging and bending (Note 2). The suitability of pipe for various purposes is somewhat dependent upon its dimensions, properties, and conditions of service, so that the purpose for which the pipe is intended should be stated in the order. The pipe may be furnished either nonexpanded or cold expanded at the option of the manufacturer. When pipe is cold expanded, the amount of expansion shall not exceed 1.5% of the outside diameter pipe size.

NOTE 1 — A comprehensive listing of standardized pipe dimensions is contained in ANSI B36.10.

NOTE 2 — This provision is not intended to prohibit the cold bending of Grade B pipe.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 865 Specification for Threaded Couplings, Steel, Black or Zinc-Coated (Galvanized) Welded and Seamless, for Use in Steel Pipe Joints

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 59 Test Method of Sampling Steel and Iron for Determination of Chemical Composition

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

2.2 *ANSI Standards:*

B1.20.1 Pipe Threads, General Purpose

B36.10 Welded and Seamless Wrought Steel Pipe

3. Process

3.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

3.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

3.3 The weld seam of electric-resistance-welded pipe in Grade B shall be heat treated after welding to a

minimum temperature of 1000°F (540°C) or processed in such a manner that no untempered martensite remains.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet or number of lengths),

4.1.2 Name of material (electric-resistance-welded pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (nominal size, or outside diameter, and nominal wall thickness),

4.1.5 Length (specific or random, Section 13),

4.1.6 End finish (plain or threaded, Section 14),

4.1.7 Alternative electric test (Section 11),

4.1.8 Skelp for tension tests (see 18.2),

4.1.9 Specification number, and

4.1.10 End use of materials.

5. Chemical Composition

5.1 The steel shall conform to the following requirements as to chemical composition:

	%, max	
Element	Grade A	Grade B
Carbon	0.25	0.30
Manganese	0.95	1.20
Phosphorus	0.035	0.035
Sulfur	0.035	0.035

6 Cast or Heat (Formerly Ladle) Analysis

6.1. An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 5. When requested by the purchaser, the chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 5.

7. Product Analysis

7.1 An analysis may be made by the purchaser on samples of pipe selected at random and shall conform to the requirements specified in Section 5. Samples for chemical analysis, except for spectrochemical analysis, shall be taken in accordance with Test Method E 59. The number of samples shall be determined as follows:

NPS	Numbers of Samples Selected
Under 6	2 from each lot of 400 pipes or fraction thereof
6 to 20, incl	2 from each lot of 200 pipes or fraction thereof
Over 20 to 30, incl	2 from each lot of 100 pipes or fraction thereof

7.2 *Retests* — If the analysis of either length of pipe or length of skelp does not conform to the requirements specified in Section 5, analyses of two additional lengths from the same lot shall be made, each of which shall conform to the requirements specified.

8. Tensile Properties

8.1 The material shall conform to the requirements as to tensile properties prescribed in Table 1.

8.2 The yield strength corresponding to a permanent offset of 0.2% of the gage length of the specimen, or to a total extension of 0.5% of the gage length under load shall be determined.

8.3 The test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe ordered. This test will not be required for pipe under NPS 8 in outside diameter.

9. Flattening Test

9.1 A specimen at least 4 in. (102 mm) in length shall be flattened cold between parallel plates in three steps with the weld located either 0° or 90° from the line of direction of force as required in 9.2. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than two thirds of the original outside diameter of the pipe. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between

the plates is less than one third of the original outside diameter of the pipe but is not less than five times the wall thickness of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

9.2 For pipe produced in single lengths, the flattening test specified in 9.1 shall be made on both crop ends cut from each length of pipe. The tests from each end shall be made alternately with the weld at 0° and at 90° from the line of direction of force. For pipe produced in multiple lengths, the flattening test shall be made on crop ends representing the front and back of each coil with the weld at 90° from the line of direction of force, and on two intermediate rings representing each coil with the weld 0° from the line of direction of force.

9.3 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 15.

9.4 Superficial ruptures as a result of surface imperfections shall not be cause for rejection.

10. Hydrostatic Test

10.1 Except as provided for in 10.3, each length of pipe shall be tested at the mill to a hydrostatic pressure calculated from the following equation, provided that in no case shall the specified test pressure exceed 2500 psi (17.2 MPa):

$$P = 2St/D$$

where:

P = minimum hydrostatic test pressure, psi,
S = allowable fiber stress 16 000 to 18 000 psi (110 to 124 MPa) for Grade A and 20 000 to 22 000 psi (138 to 152 MPa) for Grade B, but in no case shall the stress produced exceed 80% of the specified yield point,
t = specified wall thickness, in., and
D = specified outside diameter, in.

Plain end pipe may be tested at the discretion of the manufacturer in single lengths or in multiple lengths.

10.2 The hydrostatic pressure shall be maintained for not less than 5 s.

10.3 When specified in the order, pipe may be furnished without hydrostatic testing, and each length so furnished shall include with the mandatory marking the letters "NH".

NOTE 3 — This provision is not intended to apply to light wall (Schedule 10) pipe listed in Table X1.2.

10.4 When certification is required by the purchaser and the hydrostatic test has been omitted, the certification shall clearly state "Not Hydrostatically Tested". The specification number and material grade, as shown on the certification, shall be followed by the letters "NH".

11. Nondestructive Electric Test

11.1 As an alternate to the hydrostatic test for Schedule 10 pipe in nominal pipe sizes $\frac{3}{4}$ to 5 in. and when accepted by the purchaser, each pipe shall be tested with a nondestructive electric test in accordance with Practice E 213, Practice E 273, or Practice E 309. It is the intent of this test to reject pipe containing injurious defects.

11.2 In order to accommodate the various types of nondestructive electric testing equipment and techniques in use, and manufacturing practices employed, any one of the following calibration standards may be used, at the option of the manufacturer, to establish a minimum sensitivity level for rejection:

11.2.1 *Drilled Hole* — A hole not larger than 0.031 in. (0.787 mm) diameter shall be drilled radially and completely through pipe wall, preferably in the weld area, care being taken to avoid distortion of the pipe while drilling.

11.2.2 *Transverse Tangential Notch* — A notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe preferably in the weld area. Said notch shall have a depth not exceeding 12.5% of the nominal wall thickness of the pipe or 0.004 in., (0.10 mm), whichever is greater.

11.2.3 *Longitudinal Notch* — A notch 0.031 in. (0.8 mm) or less in width shall be machined in a radial plane parallel to the pipe axis on the outside surface of the pipe preferably in the weld area, to have a depth not exceeding 12.5% of the nominal wall thickness of the pipe or 0.004 in. (0.10 mm), whichever is greater.

11.3 Pipe producing a signal equal to or greater than the calibration defect shall be rejected.

11.4 Recognized methods for meeting this test are electromagnetic (eddy current) or ultrasonic.

12. Dimension, Weight, and Permissible Variations

12.1 *Weight* — The weight of any length of pipe shall not vary more than 3.5% under or 10% over that specified, but the carload weight shall be not more than 1.75% under the nominal weight. The weight of pipe furnished to Schedule 10 shall not vary more than ±10% from that prescribed in Appendix, Table X1.2.

NOTE 4 — A system of standard pipe sizes has been approved by the American National Standards Institute as American National Standard for Wrought Steel and Wrought Iron Pipe (ANSI B36.10).

12.2 *Diameter* — The outside diameter shall not vary more than ±1% from the nominal size specified.

12.3 *Thickness* — The minimum wall thickness at any point shall be not more than 12.5% under the nominal wall thickness specified.

NOTE 5 — The minimum wall thickness on inspection is shown in Table X1.1 of the Appendix.

13. Lengths

13.1 Unless otherwise specified, pipe shall be furnished in lengths averaging 38 ft (11.6 m) or over, with a minimum length of 20 ft (6.1 m), but not more than 5% may be under 32 ft (9.8 m). Jointers made by welding are permissible. When threaded pipe is ordered, jointers shall be made by threading and shall not exceed 5% of the order. Pipe furnished to Schedule 10 shall be in a specified length between 16 and 22 ft (4.9 and 6.7 m) with shorts down to 8 ft (2.4 m). Short lengths shall not exceed 10% of the footage.

14. Workmanship

14.1 *Schedule 10 Pipe* — Pipe furnished to Schedule 10 shall be plain end only. All inside and outside cutting burrs shall be removed. This generally involves breaking the corners.

14.2 *Ends, Plain End Pipe* — Unless otherwise specified, plain end pipe for use with the Dresser or Dayton type coupling shall be reamed both outside and inside sufficiently to remove all burrs. Plain end pipe for welding shall be beveled on the outside to an angle of 30° with a tolerance of +5° and −0° and with a width of flat at the end of the pipe of $\frac{1}{16} \pm \frac{1}{32}$ in. (1.6 ± 0.8 mm). When material is ordered beveled to any other than a 35° angle, it should be understood that the angle is to be measured from a line drawn perpendicular to the axis of the pipe. This means that a greater amount of material is removed with a 60° angle than with a 35° angle. Pipe shall be sufficiently free from indentations, projections, or roll marks for a distance of 8 in. (203 mm) from the end of the pipe to make a tight joint with the rubber gasket type of coupling. All plain end pipe intended for Dresser or Dayton type joints or for welding, sizes $10\frac{3}{4}$ in. (273 mm) and smaller in outside diameter, shall be not more than $\frac{1}{32}$ in. (0.8 mm) smaller than the nominal outside diameter for a distance of 8 in. (203 mm) from the end of the pipe and shall permit the passing for a distance of 8 in. (203 mm) of a ring gage which has a bore $\frac{1}{16}$ in. (1.6 mm) larger than the nominal outside diameter of the pipe. Sizes larger than $10\frac{3}{4}$ in. (273 mm) in outside diameter shall be not more than $\frac{1}{32}$ in. (0.8 mm) smaller than the nominal outside diameter for a distance of 8 in. (203 mm) from the end of the pipe and shall permit the passing for a distance of 8 in. (203 mm) of a ring gage which has a bore $\frac{3}{32}$ in. (2.4 mm) larger than the nominal outside diameter of the pipe.

14.3 *Ends, Threaded Pipe* — Each end of threaded pipe shall be reamed to remove all burrs. All threads shall be in accordance with the American National Standard Pipe Threads (Note 6) and cut so as to make a tight joint when the pipe is tested at the mill to the specified internal hydrostatic pressure. The variation from the standard, when tested with the standard working gage, shall not exceed one and one-half turns either way. Pipe shall not be rounded-out by hammering in order to get a full thread. There shall be not more than two black threads for $\frac{3}{4}$-in. (19.0-mm) taper among the perfect threads. Black threads should not be confused with imperfect threads, such as those torn, shaven, or broken.

NOTE 6 — A complete description of the American National Standard Pipe Threads applicable to pipe, valves, and fittings is contained in the American National Standard for Pipe Threads (ANSI B1.20.1); also "Screw-Thread Standards for Federal Services, 1942," National Bureau of Standards *Handbook H28*, January, 1942, the pertinent data in both sources being identical.

14.4 *Couplings* — Each length of threaded pipe shall be provided with one coupling manufactured in accordance with Specification A 865 except that the coupling may be wrought iron (Note 7). Threads shall be cut so as to make a tight joint. Taper-tapped couplings shall be furnished on all weights of threaded pipe NPS $2\frac{1}{2}$ and larger.

NOTE 7 — For sizes NPS 2 and smaller, it is commercial practice to furnish straight-tapped couplings for standard-weight (Schedule 40) pipe and taper-tapped couplings for extra-strong (Schedule 80) and double-extra-strong pipe. If taper-tapped couplings are required for sizes NPS 2 and smaller on standard weight (Schedule 40) pipe, line pipe in accordance with Specification 5L of the American Petroleum Institute should be ordered, thread lengths to be in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1). The taper-tapped couplings provided on line pipe in these sizes may be used on mill-threaded standard weight type of the same size.

15. Finish

15.1 The finished pipe shall be reasonably straight and free of injurious defects. Defects in excess of 12.5% of the nominal wall thickness shall be considered injurious.

15.2 *Repair by Welding* — Injurious defects in the pipe wall, provided their depth does not exceed one third the specified wall thickness, shall be repaired by electric welding. Defects in the welds such as sweats or leaks, unless otherwise specified, shall be repaired or the piece rejected at the option of the manufacturer. Repairs of this nature shall be made by completely removing the defect, cleaning the cavity, and then electric welding.

15.3 All repaired pipe shall be retested hydrostatically in accordance with Section 10.

16. Number of Tests

16.1 One longitudinal tension test shall be made on one length (Note 8) from each lot of 400 lengths or fraction thereof of each size under NPS 8 and one transverse body and one transverse weld tension test on one length from each lot of 200 lengths or fraction thereof of each size NPS 8 to NPS 20 and on one length from each lot of 100 lengths or fraction thereof of each size over NPS 20 to NPS 30. When taken from the skelp, the number of tests shall be determined in the same manner as when taken from the finished pipe.

NOTE 8 — Length is defined as the length as ordered, except that in the case of orders for cut lengths shorter than single random, the term lot shall apply to the lengths as rolled, prior to cutting to the required short lengths.

16.2 If any test specimen shows defective machining or develops flaws not associated with the quality of the steel or the welding, it may be discarded and another specimen substituted.

16.3 If the percentage of elongation of any tension test specimen is less than that specified in 8.1 and any part of the fracture is more than $\frac{3}{4}$ in. (19.0 mm) from the center of the gage length of a 2 in. (50 mm) specimen, as indicated by scribe scratches marked on the specimen before testing, the specimen may be discarded and another substituted.

16.4 The flattening test specified in Section 9 shall be made on both crop ends cut from each length of pipe. When pipe is produced in multiple lengths, flattening tests are required on the crop ends from the front and back ends of each coil and on two intermediate rings representing each coil.

16.5 Each length of pipe shall be subjected to the hydrostatic test specified in Section 9.

17. Retests

17.1 If the results of the tension tests of any lot do not conform to the requirements specified in Section 8, retests of two additional lengths from the same lot shall be made, each of which shall conform to the requirements specified.

17.2 If any section of the pipe fails to comply with the requirements of 9.1, for pipe produced in single lengths other sections may be cut from the same end of the same length until satisfactory tests are obtained, except that the finished pipe shall not be shorter than 80% of its length after the initial cropping; otherwise, the length shall be rejected. For pipe produced in multiple lengths, retests may be cut from each end of each individual length in the multiple; such tests shall be made with the weld alternately 0° and 90° from the line of direction of force.

18. Test Specimens and Methods of Testing

18.1 The test specimens and the tests required by these specifications shall conform to those described in Test Methods and Definitions A 370.

18.2 The longitudinal tension test specimen shall be taken from the end of the pipe, or by agreement between the manufacturer and the purchaser may be taken from the skelp, at a point approximately 90° from the weld, and shall not be flattened between gage marks. The sides of each specimen shall be parallel between gage marks.

18.3 Transverse weld test specimens shall be taken with the weld at the center of the specimen. Transverse body test specimens shall be taken opposite to the weld. All transverse test specimens shall be approximately $1\frac{1}{2}$

in. (38.1 mm) wide in the gage length and shall represent the full wall thickness of the pipe from which the specimen was cut.

18.4 All specimens shall be tested at room temperature.

19. Inspection

19.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except check analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

20. Rejection

20.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

20.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

21. Protective Coating

21.1 After the pipe has been subjected to the hydrostatic test, and if required by the purchaser, it shall be thoroughly cleaned of all dirt, oil, grease, loose scale, and rust; then dried, and given a protective coating of the kind and in the manner specified by the purchaser. Pipe furnished to Schedule 10 shall be normally shipped with a light coating of processing oil. If so specified, the pipe can be given a mill coating or a special coating.

22. Product Marking

22.1 Each length of pipe shall be legibly marked with appropriate symbols by stenciling, stamping, or rolling to show by whom manufactured, the grade of pipe, the hydrostatic test pressure when tested, or the letters "NH" when not tested, and that it conforms to this specification. When furnished without hydrostatic testing the marking shall include the letters "NH."

22.2 *Bar Coding* — In addition to the requirements in 22.1, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

23. Packaging, Marking, and Loading

23.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

TABLE 1
TENSILE REQUIREMENTS

	Grade A	Grade B
Tensile strength, min, ksi (MPa)	48 (331)	60 (414)
Yield strength, min, ksi (MPa)	30 (207)	35 (241)
Elongation in 2 in. (50 mm), min, %:		
Basic minimum elongation for walls $^{5}/_{16}$ in. (7.9 mm) and over in thickness, longitudinal strip tests, and for all small sizes tested in full section	35	30
For longitudinal strip tests, the width of the gage section shall be $1^{1}/_{2}$ in. (38.1 mm) and a deduction for each $^{1}/_{32}$ in. (0.8 mm) decrease in wall thickness below $^{5}/_{16}$ in. (7.9 mm) from the basic minimum elongation of the following percentage points	1.75[A]	1.50[A]

[A] The following table gives computed minimum values:

	Elongation in 2 in. (50 mm), min, %	
Wall Thickness, in.	Grade A	Grade B
$^{5}/_{16}$ (0.312) (7.94 mm)	35.00	30.00
$^{9}/_{32}$ (0.281) (7.14 mm)	33.25	28.50
$^{1}/_{4}$ (0.250) (6.35 mm)	31.50	27.00
$^{7}/_{32}$ (0.219) (5.56 mm)	29.75	25.50
$^{3}/_{16}$ (0.188) (4.76 mm)	28.00	24.00
$^{5}/_{32}$ (0.156) (3.97 mm)	26.25	22.50
$^{1}/_{8}$ (0.125) (3.18 mm)	24.50	21.00
$^{3}/_{32}$ (0.094) (2.38 mm)	22.75	19.50
$^{1}/_{16}$ (0.062) (1.59 mm)	21.00	18.00

NOTE — The above table gives the computed minimum elongation values for each $^{1}/_{32}$ in. (0.79 mm) decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

Grade	Equation
A	$E = 56t + 17.50$
B	$E = 48t + 15.00$

where:
E = elongation in 2 in. (50 mm), %, and
t = actual thickness of specimen, in.

APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL DATA

98

TABLE X1.1
TABLE OF MINIMUM WALL THICKNESS ON INSPECTION FOR NOMINAL (AVERAGE) PIPE WALL THICKNESSES

NOTE 1 — The following equation, upon which this table is based, may be applied to calculate minimal wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:
t_n = nominal (average) wall thickness, in., and
t_m = minimum wall thickness, in.

The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped, in accordance with Practice E 29.

NOTE 2 — This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Nominal (Average) Thickness (t_n), in. (mm)	Minimum Thickness on Inspection (t_m), in. (mm)	Nominal (Average) Thickness (t_n), in. (mm)	Minimum Thickness on Inspection (t_m), in. (mm)	Nominal (Average) Thickness (t_n), in. (mm)	Minimum Thickness on Inspection (t_m), in. (mm)
0.068 (1.73)	0.060 (1.52)	0.294 (7.47)	0.257 (6.53)	0.750 (19.05)	0.656 (16.66)
0.088 (2.24)	0.077 (1.96)	0.300 (7.62)	0.262 (6.65)	0.812 (20.62)	0.710 (18.03)
0.091 (2.31)	0.080 (2.03)	0.307 (7.80)	0.269 (6.83)	0.843 (21.41)	0.738 (18.75)
0.095 (2.41)	0.083 (2.11)	0.308 (7.82)	0.270 (6.86)	0.864 (21.95)	0.756 (19.20)
0.113 (2.87)	0.099 (2.51)	0.312 (7.92)	0.273 (6.93)	0.875 (22.23)	0.766 (19.46)
0.119 (3.02)	0.104 (2.64)	0.318 (8.08)	0.278 (7.06)	0.906 (23.01)	0.793 (20.14)
0.125 (3.18)	0.109 (2.77)	0.322 (8.18)	0.282 (7.16)	0.937 (23.80)	0.820 (20.83)
0.126 (3.20)	0.110 (2.79)	0.330 (8.38)	0.289 (7.34)	0.968 (24.59)	0.847 (21.51)
0.133 (3.38)	0.116 (2.95)	0.337 (8.56)	0.295 (7.49)	1.000 (25.40)	0.875 (22.23)
0.140 (3.56)	0.122 (3.10)	0.343 (8.71)	0.300 (7.62)	1.031 (26.19)	0.902 (22.91)
0.145 (3.68)	0.127 (3.23)	0.344 (8.74)	0.301 (7.65)	1.062 (26.97)	0.929 (23.60)
0.147 (3.73)	0.129 (3.28)	0.358 (9.09)	0.313 (7.95)	1.093 (27.76)	0.956 (24.28)
0.154 (3.91)	0.135 (3.43)	0.365 (9.27)	0.319 (8.10)	1.125 (28.58)	0.984 (24.99)
0.156 (3.96)	0.136 (3.45)	0.375 (9.53)	0.328 (8.33)	1.156 (29.36)	1.012 (25.70)
0.179 (4.55)	0.157 (3.99)	0.382 (9.70)	0.334 (8.48)	1.218 (30.94)	1.066 (27.08)
0.187 (4.75)	0.164 (4.17)	0.400 (10.16)	0.350 (8.89)	1.250 (31.75)	1.094 (27.79)
0.188 (4.78)	0.164 (4.17)	0.406 (10.31)	0.355 (9.02)	1.281 (32.54)	1.121 (28.47)
0.191 (4.85)	0.167 (4.24)	0.432 (10.97)	0.378 (9.60)	1.312 (33.33)	1.148 (29.16)
0.200 (5.08)	0.175 (4.45)	0.436 (11.07)	0.382 (9.70)	1.343 (34.11)	1.175 (29.85)
0.203 (5.16)	0.178 (4.52)	0.437 (11.10)	0.382 (9.70)	1.375 (34.93)	1.203 (30.56)
0.216 (5.49)	0.189 (4.80)	0.438 (11.13)	0.383 (9.73)	1.406 (35.71)	1.230 (31.24)
0.218 (5.54)	0.191 (4.85)	0.500 (12.70)	0.438 (11.13)	1.437 (36.53)	1.258 (31.95)
0.219 (5.56)	0.192 (4.88)	0.531 (13.49)	0.465 (11.81)	1.500 (38.10)	1.312 (33.33)
0.226 (5.74)	0.198 (5.03)	0.552 (14.02)	0.483 (12.27)	1.531 (38.89)	1.340 (34.04)
0.237 (6.02)	0.207 (5.26)	0.562 (14.27)	0.492 (12.50)	1.562 (39.68)	1.367 (34.72)
0.250 (6.35)	0.219 (5.56)	0.593 (15.06)	0.519 (13.18)	1.593 (40.46)	1.394 (35.41)
0.258 (6.55)	0.226 (5.74)	0.600 (15.24)	0.525 (13.34)	1.750 (44.45)	1.531 (38.89)
0.276 (7.01)	0.242 (6.15)	0.625 (15.88)	0.547 (13.89)	1.781 (45.24)	1.558 (39.57)
0.277 (7.04)	0.242 (6.15)	0.656 (16.66)	0.574 (14.58)	1.812 (46.03)	1.586 (40.28)
0.279 (7.09)	0.244 (6.20)	0.674 (17.12)	0.590 (14.99)	1.968 (49.99)	1.722 (43.74)
0.280 (7.11)	0.245 (6.22)	0.687 (17.45)	0.601 (15.27)	2.062 (52.38)	1.804 (45.82)
0.281 (7.14)	0.246 (6.25)	0.719 (18.24)	0.629 (15.98)	2.343 (59.51)	2.050 (52.07)

TABLE X1.2
DIMENSIONS NOMINAL WEIGHTS AND TEST PRESSURES FOR LIGHT WALL STEEL PIPE

		Schedule 10		Test Pressure, psi (MPa)[A]	
NPS	Outside Diameter, in.	Nominal Wall Thickness[A] in. (mm)	Weight, lb/ft (kg/cm)	Grade A	Grade B
3/4	1.050	0.083 (2.11)	0.86 (1.28)	2500 (17.24)	2500 (17.24)
1	1.315	0.109 (2.77)	1.40 (2.09)	2500 (17.24)	2500 (17.24)
1 1/4	1.660	0.109 (2.77)	1.81 (2.70)	2400 (16.55)	2500 (17.24)
1 1/2	1.900	0.109 (2.77)	2.08 (3.10)	2100 (14.48)	2400 (16.55)
2	2.375	0.109 (2.77)	2.64 (3.93)	1700 (11.72)	1900 (13.10)
2 1/2	2.875	0.120 (3.05)	3.53 (5.26)	1500 (10.34)	1700 (11.72)
3	3.500	0.120 (3.05)	4.33 (6.45)	1200 (8.27)	1400 (9.65)
3 1/2	4.000	0.120 (3.05)	4.97 (7.41)	1000 (6.89)	1200 (8.27)
4	4.500	0.120 (3.05)	5.61 (8.36)	900 (6.21)	1100 (7.58)
5	5.563	0.134 (3.40)	7.77 (11.58)	850 (5.86)	1000 (6.89)

[A] The test pressures are calculated by the following equation (but shall not exceed 2500 psi or 17.24 MPa):

$$P = 2St/D$$

where:
P = pressure, psi (MPa)
S = fiber stress, 60% of the specified minimum yield point,
t = specified thickness of wall, in. (mm), and
D = specified outside diameter, in. (mm).

SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED CARBON STEEL AND CARBON-MANGANESE STEEL BOILER AND SUPERHEATER TUBES

SA-178/SA-178M

(Identical with ASTM Specification A 178/A 178M-95)

1. Scope

1.1 This specification covers minimum-wall-thickness, electric-resistance-welded tubes made of carbon steel and carbon-manganese steel intended for use as boiler tubes, boiler flues, superheater flues, and safe ends.

NOTE 1 — Type C and D tubes are not suitable for safe-ending for forge welding.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ½ to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.320 in. [0.9 to 9.1 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520 shall supplement and supersede the requirements of this specification.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 226/A 226M Specification for Electric-Resistance-Welded Carbon Steel Boiler and Superheater Tubes for High-Pressure Service

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction.

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (electric-resistance-welded tubes),

3.1.3 Grade (A, C, or D, Table 1),

3.1.4 Size (outside diameter and minimum wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirements (product analysis, Section 7; crush test, Section 10; hydrostatic or nondestructive electric test, 11.6),

3.1.7 Test report required (Certification Section of Specification A 450/A 450M),

3.1.8 Specification, and designation,

3.1.9 Individual supplementary requirements, if required, and

3.1.10 Special requirements.

4. Manufacture

4.1 The steel for Grade D shall be killed.

4.2 Tubes shall be made by electric-resistance welding.

5. Heat Treatment

5.1 After welding, all tubes shall be heat treated at a temperature of 1650°F [900°C] or higher and followed by cooling in air or in the cooling chamber of a controlled-atmosphere furnace. Cold-drawn tubes shall be heat treated after the final cold-draw pass at a temperature of 1200° [650°C] or higher.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 When a grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed in Table 1 is not permitted.

7. Product Analysis

7.1 When requested on the purchase order, a product analysis shall be made by the manufacturer or supplier from one tube per 100 pieces for sizes over 3 in. [76.2 mm] and one tube per 250 pieces for sizes 3 in. [76.2 mm] and under; or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

7.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specifications shall be rejected.

NOTE 2 — A lot consists of 250 tubes for sizes 3 in. [76.2 mm] and under and of 100 tubes for sizes over 3 in. [76.2 mm], prior to cutting to length.

8. General Requirements

8.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M unless otherwise provided herein.

9. Tensile Requirements

9.1 Grade C and D tubes shall conform to the requirements as to tensile properties prescribed in Table 2.

NOTE 3: *Explanatory Note* — For purposes of design the following tensile properties may be assumed for Grade A tubes:

Tensile strength, min, ksi [MPa]	47 [325]
Yield Strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

10. Crush Test

10.1 When required by the purchaser, crushing tests shall be made on sections of tube 2½ in. [63 mm] in length which shall stand crushing longitudinally without cracking, splitting, or opening at the weld, as follows:

Wall Thickness of Tubes, in. [mm]	Height of Crushed Section, in. [mm]	
	Grade A Tubes	Grade C and D Tubes
0.135 [3.43] and under	¾ [19] or until outside folds are in contact	Crush tests not required
Over 0.135 [3.43]	1¼ [32]	. . .

10.2 Table 3 gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00 \quad [E = 1.87t + 15.00]$$

where:

E = elongation in 2 in. or 50 mm, %, and,
t = actual thickness of specimen, in. [mm].

10.3 For tubing less than 1 in. [25.4 mm] in outside diameter, the length of the specimen shall be $2\frac{1}{2}$ times the outside diameter of the tube. Slight surface checks shall not be cause for rejection.

11. Mechanical Tests Required

11.1 *Flattening Test:*

11.1.1 For Grade A, one flattening test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof, and from each 2000 ft [600 m] or fraction thereof of safe-end material.

11.1.2 For Grades C and D, one flattening test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

11.2 *Flange Test:*

11.2.1 For Grade A, one flange test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof, and from each 2000 ft [600 m] or fraction thereof of safe-end material.

11.2.2 For Grades C and D, one flange test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof. The width of the flange shall not be less than 75% of that specified in Specification A 450/A 450M.

11.3 *Crush Test* — For Grade A, when required by the purchaser, one crush test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof, and from each 2000 ft [600 m] or fraction thereof of safe-end material.

11.4 *Tension Test* — For Grades C and D, one tension test shall be made on specimens from each of two tubes from each lot. The term *lot* for tension test requirements applies to all tubes prior to cutting, of the same nominal diameter and wall thickness, which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace, at the same temperature, time at heat, and furnace speed.

11.5 *Reverse Flattening Test* — One reverse flattening test shall be made on each 1500 ft [450 m] of finished tubing.

11.6 *Hydrostatic or Nondestructive Electric Test* — Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

12. Forming Operations

12.1 When inserted in the boiler, tubes shall withstand expanding and beading without showing cracks or flaws, or opening at the weld. When properly manipulated, superheater tubes shall withstand all forging, welding, and bending operations necessary for application without developing defects.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 450/A 450M, the letters “ERW” shall be legibly stenciled on each tube, or marked on a tag attached to the bundle or box in which the tubes are shipped.

13.2 The manufacturer’s name or symbol may be placed permanently on each tube by rolling or light stamping before normalizing. If a single stamp is placed on the tube by hand, this mark should not be less than 8 in. [200 mm] from one end of the tube.

14. Keywords

14.1 boiler tube; resistance welded steel tube; steel tube, carbon; welded steel tube

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A, Low-Carbon Steel	Grade C, Medium-Carbon Steel	Grade D, Carbon-Manganese Steel
Carbon	0.06–0.18	0.35 max	0.27 max
Manganese	0.27–0.63	0.80 max	1.00–1.50
Phosphorus, max	0.035	0.035	0.030
Sulfur, max	0.035	0.035	0.015
Silicon	. . .	. . .	0.10 min

98

TABLE 2
TENSILE REQUIREMENTS

	Grade C	Grade D
Tensile strength, min, ksi [MPa]	60 [415]	70 [485]
Yield strength, min, ksi [MPa]	37 [255]	40 [275]
Elongation in 2 in. or 50 mm, min, %	30	30
For longitudinal strip tests a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points shall be made.	1.50[A]	1.50[A]

[A] See Table 3 for the computed minimum values:

TABLE 3
MINIMUM ELONGATION VALUES

Wall Thickness		Elongation in 2 in. or 50 mm, min, %[A]
in.	mm	
$\frac{5}{16}$ (0.312)	8	30
$\frac{9}{32}$ (0.281)	7.2	29
$\frac{1}{4}$ (0.250)	6.4	27
$\frac{7}{32}$ (0.219)	5.6	26
$\frac{3}{16}$ (0.188)	4.8	24
$\frac{5}{32}$ (0.156)	4	22
$\frac{1}{8}$ (0.125)	3.2	21
$\frac{3}{32}$ (0.094)	2.4	20
$\frac{1}{16}$ (0.062)	1.6	18

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and production order or contract. These requirements shall not be considered, unless specified in the order and the necessary tests shall be made at the mill.

S1. Additional Testing of Welded Tubing for ASME Requirements

S1.1 The weld seam of each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 450/A 450M.

S1.2 If Practice E 273 is employed, a 100% volumetric inspection of the entire length of each tube shall also be performed using one of the nondestructive electric tests permitted by Specification A 450/A 450M.

S1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S1.4 In addition to the marking prescribed in Specification A 450/A 450M, “S1” shall be added after the grade designation.

SPECIFICATION FOR SEAMLESS COLD-DRAWN LOW-CARBON STEEL HEAT-EXCHANGER AND CONDENSER TUBES

SA-179/SA-179M

(Identical with ASTM Specification A 179/A 179M-90a)

1. Scope

1.1 This specification covers minimum-wall-thickness, seamless cold-drawn low-carbon steel tubes for tubular heat exchangers, condensers, and similar heat transfer apparatus.

1.2 This specification covers tubes $\frac{1}{8}$ to 3 in. [3.2 to 76.2 mm], inclusive, in outside diameter.

NOTE 1 — Tubing smaller in outside diameter and having a thinner wall than indicated in this specification is available. Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in outside diameter or with a wall thickness under 0.015 in. [0.4 mm].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Document

2.1 *ASTM Standard:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quality (feet, metres, or number of lengths),

4.1.2 Name of material (seamless tubes),

4.1.3 Manufacture (cold-drawn),

4.1.4 Size (outside diameter and minimum wall thickness),

4.1.5 Length (specific or random),

4.1.6 Optional requirements (product analysis, Section 9, flange test, 11.3),

4.1.7 Test report required (Certification Section of Specification A 450/A 450M),

4.1.8 Specification number, and

4.1.9 Special requirements.

5. Manufacture

5.1 Tubes shall be made by the seamless process and shall be cold drawn.

6. Heat Treatment

6.1 Tubes shall be heat treated after the final cold draw pass at a temperature of 1200°F [650°C] or higher.

7. Surface Condition

7.1 Finished tubes shall be free of scale. A slight amount of oxidation will not be considered as scale.

8. Chemical Composition

8.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, %	0.06–0.18
Manganese, %	0.27–0.63
Phosphorus, max, %	0.035
Sulfur, max, %	0.035

8.2 Supplying an alloy grade that specifically requires the addition of any element other than those listed in 8.1 is not permitted.

9. Product Analysis

9.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube per 250 pieces or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

9.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question shall meet the requirements of this specification; otherwise all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 2 — A lot consists of 250 tubes.

10. Hardness Requirements

10.1 The tube shall have a hardness number not exceeding 72 HRB.

11. Mechanical Tests Required

11.1 *Flattening Test* — One flattening test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

11.2 *Flaring Test* — One flaring test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

11.3 *Flange Test* — When specified as a substitute for the flaring test, for tubes having a wall thickness (actual mean wall) less than 10% of the outside diameter, one test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof. For tubes other than specified above, the flange test shall not be required.

11.4 *Hardness Test* — Rockwell hardness tests shall be made on specimens from two tubes from each lot. The term *lot* applies to all tubes, prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

11.5 *Hydrostatic Test* — Each tube shall be subjected to the hydrostatic test, or instead of this test, a nondestructive electric test may be used when specified by the purchaser.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include the name and order number of the purchaser.

EXPLANATORY NOTE

NOTE — For purposes of design, the following tensile properties may be assumed:

Tensile strength, min, ksi [MPa]	47 [325]
Yield strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

SPECIFICATION FOR CARBON STEEL FORGINGS, FOR GENERAL-PURPOSE PIPING

98

SA-181/SA-181M

(Identical with ASTM Specification A 181/A 181M-95b except for editorial differences in 7.3.2 and 12.6)

1. Scope

1.1 This specification covers nonstandard as-forged fittings, valve components, and parts for general service. Forgings made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. Larger forgings may be ordered to Specification A 266.

1.2 Two grades of material are covered, designated as Classes 60 and 70, respectively, and are classified in accordance with their chemical composition and mechanical properties as specified in 5.1 and 6.1.

1.3 Class 60 was formerly designated Grade I and Class 70 was formerly designated Grade II.

1.4 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 266 Specification for Forgings, Carbon Steel, for Pressure Vessel Components

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 788 Specification for Steel Forgings, General Requirements

E 165 Test Methods for Liquid Penetrant Inspection Method

E 709 Guide for Magnetic Particle Examination

2.2 *ASME Boiler and Pressure Vessel Code:*

Section IX, Welding Qualifications

Section VIII, Pressure Vessels, Div. 1

2.3 *Military Standard:*

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.4 *AIAG Standard:*

AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

3.1.1 Quantity,

3.1.2 Dimensions (Tolerances and surface finishes should be included),

3.1.3 Specification number (The year date should be included) and class,

3.1.4 Supplementary requirements, and

3.1.5 Additional requirements (See 4.6, 12.2, 10, 12.7, 17.2, 18.1, 18.2, and 11.1).

4. Materials and Manufacture

4.1 The steel shall be made by the open-hearth, basic-oxygen, or electric-furnace process and shall be fully killed.

4.2 A sufficient discard shall be made from source material to secure freedom from injurious piping and undue segregation.

4.3 The material shall be forged as close as practicable to the specified shape and size.

4.4 Except for flanges of all types, hollow, cylindrically shaped parts may be machined from hot-rolled or forged bar, provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Other parts, excluding flanges of all types, up to and including NPS 4 may be machined from hot-rolled or forged bar. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.5 Except as permitted in 4.4, the finished product shall be a forging as defined in the Terminology section (exclusively) of Specification A 788.

4.6 When specified in the order, the manufacturer shall submit for approval of the purchaser a sketch showing the shape of the rough forging before machining.

4.7 Forgings shall be protected against sudden or too rapid cooling from the rolling or forging while passing through the critical range.

4.8 Heat treatment is neither required nor prohibited, but when applied, heat treatment shall consist of tempering, annealing, normalizing, or normalizing and tempering.

5. Chemical Composition

5.1 *Cast or Heat Analysis*— An analysis of each cast or heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The analysis shall be made from a test sample taken preferably during the pouring of the cast or heat. The chemical composition thus determined shall conform to the requirements in Table 1.

5.2 *Product Analysis:*

5.2.1 The purchaser may make a product analysis on forgings supplied to this specification by any of the commonly accepted methods that will positively identify the material. Samples for analysis may be taken from midway between center and surface of solid forgings, midway between inner and outer surfaces of hollow forgings, midway between center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 1 within the permissible variations of Table 2.

5.2.2 Test Methods, Practices, and Terminology A 751 shall apply.

6. Mechanical Properties

6.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

6.2 Testing shall be performed in accordance with Test Methods and Definitions A 370.

7. Workmanship, Finish, and Appearance

7.1 The forgings shall be free of injurious imperfections as defined below and shall have a workmanlike finish. At the discretion of the inspector representing the purchaser, finished forgings shall be subject to rejection if surface imperfections acceptable under 7.3 are not scattered but appear over a large area in excess of what is considered a workmanlike finish.

7.2 *Depth of Injurious Imperfections* — Selected typical linear and other typical surface imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness of the finished forging, such imperfections shall be considered injurious.

7.3 *Machining or Grinding Imperfections Not Classified as Injurious* — Surface imperfections not classified as injurious shall be treated as follows:

7.3.1 Forgings showing seams, laps, tears, or slivers not deeper than 5% of the nominal wall thickness or $\frac{1}{16}$ in. [1.6 mm], whichever is less, need not have these imperfections removed. If the imperfections require removal, they shall be removed by machining or grinding.

7.3.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed the limitations set forth in

7.2 and if not deeper than $^{1}/_{16}$ in. [1.6 mm]. If such imperfections are deeper than $^{1}/_{16}$ in. [1.6 mm] but do not encroach on the minimum wall thickness of the forging they shall be removed by grinding to sound metal.

7.3.3 When imperfections have been removed by grinding or machining, the outside dimension at the point of grinding or machining may be reduced by the amount removed. Should it be impracticable to secure a direct measurement, the wall thickness at the point of grinding, or at imperfections not required to be removed, shall be determined by deducting the amount removed by grinding, from the nominal finished wall thickness of the forging, and the remainder shall not be less than the minimum specified or required wall thickness.

8. Number of Tests

8.1 One tension test shall be made from each heat.

8.2 If any test specimen is defectively machined, it may be discarded and another specimen substituted.

9. Retests

9.1 When one or more representative test specimens do not conform to specification requirements for the tested characteristic, only a single retest for each nonconforming characteristic may be performed to establish product acceptability. Retests shall be performed on twice the number of representative specimens that were originally nonconforming. When any retest specimen does not conform to specification requirements for the characteristic in question, the lot represented by that specimen shall be rejected, heat-treated or reheat-treated in accordance with 4.8, and tested in accordance with Sections 6, 8, and 10.

10. Test Specimens

10.1 The tension test specimens shall be machined to the form and dimensions of the standard 2 in. [50 mm] gage length tension test specimen shown in Fig. 4 of Test Methods and Definitions A 370, except as specified in 10.2.

10.2 In the case of small sections which will not permit the taking of standard test specimen specified in 10.1, the tension test specimen shall be as large as feasible and its dimensions shall be proportional to those shown in Fig. 4 of Test Methods and Definitions A 370. The gage length for measuring elongation shall be four times the diameter of the specimen.

10.3 For the purpose of determining conformance to Table 3, specimens shall be obtained from the production forgings, or from separately forged test blanks prepared from the stock used to make the finished product. Such test blanks shall receive approximately the same working as the finished product.

11. Reports of Testing

11.1 Upon request of the purchaser in the contract or order, a report of the test results and chemical analyses shall be furnished. The specification designation included on reports of testing shall include year of issue and revision letter, if any.

12. Repair by Welding

12.1 Repair welding, by the manufacturer, is permissible for parts made to dimensional standards such as those of ANSI or equivalent standards.

12.2 Prior approval of the purchaser shall be required to weld repair special parts made to the purchaser's requirements.

12.3 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

12.4 The composition of the weld deposits shall be similar to the base metal and in accordance with the procedure qualification for the applicable material. Welding shall be accomplished with a weld procedure designed to produce low hydrogen in the weldment. Short-circuit gas metal arc welding is permissible only with the approval of the purchaser.

12.5 Unacceptable imperfections shall be removed by mechanical means or thermal cutting or gouging methods. Cavities prepared for welding shall be examined by one of the following methods to verify removal of the imperfection:

12.5.1 Magnetic particle examination in accordance with Test Method A 275 or Guide E 709.

12.5.2 Liquid penetrant examination in accordance with Test Method E 165.

12.6 Weld repaired area(s) shall be blended uniformly to the base metal and shall be examined by the same method used for 12.5.

12.7 Repair by welding shall neither exceed 10 % of the surface area of the part, nor $33^{1}/_{3}$ % of the wall thickness of the finished product at the location of repair, without prior approval of the purchaser.

13. Marking of Forgings

13.1 Identification marks consisting of the manufacturer's symbol or name (Note), designation of service rating, Specification number, grade, and size shall be legibly forged or stamped on each forging, and in such a position as not to injure the usefulness of the forgings. The specification number marked on the forgings need not include specification year of issue and revision letter.

NOTE 1 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

13.2 *Bar Coding* — In addition to the requirements in 13.1, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

15. Rejection

15.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

16. Rehearing

16.1 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

17. Packaging, Marking, and Loading for Shipment

17.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

17.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, when level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

18. Certificate of Compliance

18.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. The specification designation included on certificates of compliance shall include year of issue and revision letter, if any.

18.2 When specified in the purchase order or contract, a report of the test results shall be furnished.

19. Keywords

19.1 pipe fittings; steel; piping applications; pressure containing parts; steel forgings; carbon; steel valves

TABLE 1 98
CHEMICAL REQUIREMENTS

Element	Composition, % Classes 60 and 70
Carbon, max	0.35
Manganese, max	1.10[A]
Phosphorus, max	0.05
Silicon, max	0.10–0.35
Sulfur, max	0.05

[A] Manganese may be increased to 1.35% max provided the carbon is reduced 0.01% for each 0.06% increase in manganese over the limit shown in the table.

TABLE 2 98
PERMISSIBLE VARIATIONS IN PRODUCT ANALYSIS

NOTE 1 — Product cross-sectional area (taken at right angles to the axis of the original ingot or billet) is defined as either:
(a) maximum cross-sectional area of rough machined forging (excluding boring),
(b) maximum cross-sectional area of the unmachined forging, or
(c) maximum cross-sectional area of the billet, bloom or slab.

	Permissible Variations over the Maximum Limit or Under the Minimum Limit, %				
	200 in.^{2} [1290 cm^2] and under	Over 200 to 400 in.^{2} [1290 to 2580 cm^2] incl	Over 400 to 800 in.^{2} [2580 to 5160 cm^2] incl	Over 800 to 1600 in.^{2} [5160 to 10 320 cm^2]	Over 1600 in.^{2} [10 320 cm^2]
Manganese					
Up to and including 0.90	0.04	0.05	0.06	0.07	0.08
0.91 and over	0.06	0.07	0.08	0.08	0.09
Phosphorus	0.008	0.010	0.010	0.015	0.015
Sulfur	0.010	0.010	0.010	0.015	0.015
Silicon	0.03	0.04	0.04	0.05	0.06

TABLE 3
TENSILE REQUIREMENTS

	Class 60	Class 70
Tensile strength, min, ksi [MPa]	60 [415]	70 [485]
Yield strength,[A] min, ksi [MPa]	30 [205]	36 [250]
Elongation in 2 in. [50 mm], min, %	22	18
Reduction of area, min, %	35	24

[A] Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

SUPPLEMENTARY REQUIREMENTS

S1. Carbon Equivalent

S1.1 The maximum carbon equivalent based on heat analysis shall be as follows:

	Maximum Carbon Equivalent Value	
Class	Maximum Section Thickness Less Than or Equal to 2 in.	Maximum Section Thickness Greater Than 2 in.
60	0.45	0.46
70	0.47	0.48

S1.2 Determine the carbon equivalent (CE) as follows:

$$CE = Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S1.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

S1.4 When this Supplementary Requirement is invoked, all elements in the carbon equivalent formula shall be analyzed and the amounts reported.

SPECIFICATION FOR FORGED OR ROLLED ALLOY-STEEL PIPE FLANGES, FORGED FITTINGS, AND VALVES AND PARTS FOR HIGH-TEMPERATURE SERVICE

SA-182/SA-182M

(Identical with ASTM Specification A 182/A 182M-96 except for the clarified heat treatment requirements by the addition of Note 4 to Table 1.) 98

1. Scope

1.1 This specification covers forged low alloy and stainless steel piping components for use in pressure systems. Included are flanges, fittings, valves, and similar parts to specified dimensions or to dimensional standards such as the ANSI specifications that are referenced in Section 2.

1.2 For bars and products machined directly from bar, refer to Specifications A 479/A 479M and A 739 for the similar grades available in those specifications. Products made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. For larger products and products for other applications refer to Specification A 336 for the similar grades available in that specification.

98 **1.3** Several grades of low alloy steels and ferritic, martensitic, austenitic, and ferritic/austenitic stainless steels are included in this specification. Selection will depend upon design and service requirements.

1.4 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The value stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 234/A 234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 336/A 336M Specification for Steel Forgings, Alloy, for Pressure and High-Temperature Parts

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 403/A 403M Specification for Wrought Austenitic Stainless Steel Piping Fittings

A 479/A 479M Specification for Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

A 484/A 484M Specification for General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings

A 739 Specification for Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels
A 788 Specification for Steel Forgings, General Requirements
E 112 Test Methods for Determining the Average Grain Size
E 165 Practice for Liquid Penetrant Inspection Method
E 340 Test Method for Macroetching Metals and Alloys

2.2 *MSS Standard:*
SP 25 Standard Marking System for Valves, Fittings, Flanges and Unions

2.3 *ASME Boiler and Pressure Vessel Codes:*
Section IX Welding Qualifications
SFA-5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes
SFA-5.5 Specification for Low-Alloy Steel Covered Arc-Welding Electrodes
SFA-5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes
SFA-5.11 Specification for Nickel and Nickel-Alloy Covered Welding Electrodes

2.4 *ANSI Standards:*
B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings
B16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves
B16.11 Forged Steel Fittings, Socket Weld, and Threaded

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

3.1.1 Quantity,

3.1.2 Size and pressure class or dimensions (Tolerances and surface finishes should be included),

3.1.3 Specification number, grade, and class if applicable (The year date should be included),

3.1.4 Supplementary requirements,

3.1.5 Additional requirements (See 5.1.2, Table 2 footnotes, 15.1, and 15.2), and

3.1.6 Requirement, if any, that manufacturer shall submit drawings for approval showing the shape of the rough forging before machining and the exact location of test specimen material (see 7.3.1).

4. Manufacture

4.1 The low-alloy ferritic steels may be made by the open-hearth, electric-furnace, or basic-oxygen process with separate degassing and refining optional. The basic-oxygen process shall be limited to steels containing not over 6% chromium.

4.2 The stainless steels shall be melted by one of the following processes: (*a*) electric-furnace (with separate degassing and refining optional); (*b*) vacuum-furnace; or (*c*) one of the former followed by vacuum or electrolag-consumable remelting. Grade F XM-27Cb may be produced by electron-beam melting. Because of difficulties that may be met in retaining nitrogen, vacuum melting or remelting processes should not be specified for Grades F XM-11, F 304LN, F 316LN, F 304N, F 316N, F XM-19, F 44, F 45, F 48, F 49, F 50, F 51, F 52, F 53, F 54, or F 55.

4.3 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

4.4 The material shall be forged as close as practicable to the specified shape and size. Except for flanges of any type, forged or rolled bar may be used without additional hot working for small cylindrically shaped parts within the limits defined by Specification A 234/A 234M for low alloy steels and martensitic stainless steels and Specification A 403/A 403M for austenitic and ferritic-austenitic stainless steels. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.5 Except as provided for in 4.4, the finished product shall be a forging as defined in the Terminology section of Specification A 788.

5. Heat Treatment

5.1 After hot working, forgings shall be cooled to a temperature below 1000°F [538°C] prior to heat treating in accordance with the requirements of Table 1.

5.2 *Low Alloy Steels and Ferritic and Martensitic Stainless Steels* — The low alloy steels and ferritic

and martensitic stainless steels shall be heat treated in accordance with the requirements of 5.1 and Table 1.

5.2.1 Grade F 22V shall be furnished in the normalized and tempered, or liquid quenched and tempered condition. The minimum austenitizing temperature shall be 1650°F [900°C], and the minimum tempering temperature shall be 1250°F [677°C].

5.2.2 *Liquid Quenching* — When agreed to by the purchaser, liquid quenching followed by tempering shall be permitted provided the temperatures in Table 1 for each grade are utilized.

5.2.2.1 *Marking* — Parts that are liquid quenched and tempered shall be marked "QT."

98 **5.2.3** Alternatively, Grade F1, F2, and F12, Classes one and two may be given a heat treatment of 1200°F (650°C) minimum after final hot of cold forming.

5.3 *Austenitic and Ferritic-Austenitic Stainless Steels* — The austenitic and ferritic-austenitic stainless steels shall be heat treated in accordance with the requirements of 5.1 and Table 1.

5.3.1 Alternatively, immediately following hot working, while the temperature of the forging is not less than the minimum solutioning temperature specified in Table 1, forgings made from austenitic grades (except grades F304H, F316H, F321, F321H, F347, F347H, F348, and F348H) may be individually rapidly quenched in accordance with the requirements of Table 1.

5.3.2 See Supplementary Requirement S15 if a particular heat treatment method is to be employed.

5.4 *Time of Heat Treatment* — Heat treatment of forgings may be performed before machining.

5.5 *Forged or Rolled Bar* — Forged or rolled austenitic stainless bar from which small cylindrically shaped parts are to be machined, as permitted by 4.4, and the parts machined from such bar, without heat treatment after machining, shall be furnished to the annealing requirements of Specification A 479 or this specification, with subsequent light cold drawing and straightening permitted (see Supplementary Requirement S9 if annealing must be the final operation).

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition for the grade ordered as listed in Table 2. Test Methods, Practices, and Terminology A 751 shall apply.

6.2 Grades to which lead, selenium, or other elements are added for the purpose of rendering the material free-machining shall not be used.

6.3 Starting material produced to a specification that specifically requires the addition of any element beyond those listed in Table 2 for the applicable grade of material, is not permitted.

7. Mechanical Properties

7.1 The material shall conform to the requirements as to mechanical properties for the grade ordered as listed in Table 3.

7.2 Mechanical test specimens shall be obtained from production forgings, or from separately forged test blanks prepared from the stock used to make the finished product. In either case, mechanical test specimens shall not be removed until after all heat treatment is complete. If repair welding is required, test specimens shall not be removed until after post-weld heat treatment is complete, except for ferritic grades when the post-weld heat treatment is conducted at least 50°F [30°C] below the actual tempering temperature. When test blanks are used, they shall receive approximately the same working as the finished product. The test blanks shall be heat treated with the finished product and shall approximate the maximum cross section of the forgings they represent.

7.3 For normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the $\frac{1}{4}$ T plane or deeper position where T is the maximum heat treated thickness of the represented forging. In addition, for quenched and tempered forgings, the midlength of the test specimen shall be at least T from any second heat treated surface. When the section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location, as agreed to by the purchaser and the supplier.

7.3.1 With prior to purchase approval, the test specimen for ferritic steel forgings, may be taken at a depth (t) corresponding to the distance from the area of significant stress to the nearest heat treated surface and at least twice this distance ($2t$) from any second surface. However, the test depth shall not be nearer to one treated surface than $\frac{3}{4}$ in. [19 mm] and to the second treated surface than $1\frac{1}{2}$ in. [38 mm]. This method of test specimen location would normally apply to contour-forged parts, or parts with thick cross-sectional areas where $\frac{1}{4}$ $T \times T$ testing (7.3) is practical.

Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

7.4 For annealed low alloy steel, ferritic stainless steels, and martensitic stainless steels and also for austenitic and ferritic-austenitic stainless steels, the test specimen may be taken from any convenient location.

7.5 *Tension Tests:*

7.5.1 *Low Alloy Steels and Ferritic and Martensitic Stainless Steels* — One tension test shall be made for each heat in each heat treatment charge.

7.5.1.1 When the heat-treating cycles are the same and the furnaces (either batch or continuous type) are controlled within ±25°F [±14°C] and equipped with recording pyrometers so that complete records of heat treatment are available, then only one tension test from each heat of each forging type (Note 1) and section size is required instead of one test from each heat in each heat-treatment charge.

NOTE 1 — "Type" in this case is used to describe the forging shape such as a flange, ell, tee, etc.

7.5.2 *Austenitic and Ferritic-Austenitic Stainless Steel Grades* — One tension test shall be made for each heat.

7.5.2.1 When heat treated in accordance with 5.1, the test blank or forging used to provide the test specimen shall be heat treated with a finished forged product.

7.5.2.2 When the alternative method in 5.3.1 is used, the test blank or forging used to provide the test specimen shall be forged and quenched under the same processing conditions as the forging they represent.

7.5.3 Testing shall be performed in accordance with Test Methods and Definitions A 370 using the largest feasible of the round specimens. The gage length for measuring elongation shall be four times the diameter of the test section.

7.6 *Hardness Test:*

7.6.1 Except when only one forging is produced, a minimum of two pieces per batch or continuous run as defined in 7.6.2 shall be hardness tested in accordance with Test Methods and Definitions A 370 to ensure that the forgings are within the hardness limits given for each grade in Table 3. The purchaser may verify that the requirement has been met by testing at any location on the forging provided such testing does not render the forging useless.

7.6.2 When the reduced number of tension tests permitted by 7.5.1.1 is applied, additional hardness tests shall be made on forgings or samples as defined in 7.2 scattered throughout the load (Note 2). At least eight samples shall be checked from each batch load and at least one check per hour shall be made from a continuous run. When the furnace batch is less than eight forgings, each forging shall be checked. If any check falls outside the prescribed limits, the entire lot of forgings shall be reheat treated and the requirements of 7.5.1 shall apply.

NOTE 2 — The tension test required in 7.5.1 is used to determine material capability and conformance in addition to verifying the adequacy of the heat-treatment cycle. Additional hardness tests in accordance with 7.6.2 are required when 7.5.1.1 is applied to assure the prescribed heat-treating cycle and uniformity throughout the load.

7.7 *Notch Toughness Requirements* — Grades F3V, F3VCb, and F22V.

7.7.1 Impact test specimens shall be Charpy V-notch Type, as shown in Fig. 10a of Test Methods and Definitions A 370. The usage of subsize specimens due to material limitations must have prior purchaser approval.

7.7.2 The Charpy V-notch test specimens shall be obtained as required for tension tests in 7.2, 7.3 and 7.5. One set of three Charpy V-notch specimens shall be taken from each tensile specimen location.

7.7.3 The longitudinal axis and mid-length of impact specimen shall be located similarly to the longitudinal axis of the tension test specimens. The axis of the notch shall be normal to the nearest heat treated surface of the forging.

7.7.4 The Charpy V-notch tests shall meet a minimum energy absorption value of 40 ft-lbf [54 J] average of three specimens. One specimen only in one set may be below 40 ft-lbf [54 J], and it shall meet a minimum value of 35 ft-lbf [48 J].

7.7.5 The impact tests temperature shall be 0°F [−18°C].

8. Grain Size for Austenitic Grades

8.1 All H grades shall be tested for average grain size by Test Methods E 112.

8.1.1 Grades F304H, F309H, F310H, and F316H shall have a grain size of ASTM No. 6 or coarser.

8.1.2 Grades F321H, F347H, and F348H shall have a grain size of ASTM No. 7 or coarser.

9. Corrosion Testing for Austenitic Grades

9.1 Corrosion testing is not required by this specification.

9.2 Austenitic Grades shall be capable of meeting the intergranular corrosion test requirements described in Supplementary Requirement S10.

10. Cast or Heat (formerly Ladle) Analysis

10.1 Each heat or furnace ladle of steel shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 2. This analysis shall be made from a test specimen preferably taken during the pouring of the steel. For multiple-heat ingots, either individual heat analyses or a weighted average analysis may be reported. The steel shall conform to the chemical composition requirements prescribed in Table 2.

10.1.1 If the test sample is lost or declared inadequate for chemical determinations, the manufacturer may take alternative samples from appropriate locations near the surface of the ingot or forging as necessary to establish the analysis of the heat in question.

10.1.2 If consumable remelting processes are employed, a chemical analysis made on one remelted ingot (or the product of one remelted ingot) per heat shall be taken as the heat analysis, and shall conform to the chemical composition requirements prescribed in Table 2. For this purpose, a heat is defined as all of the ingots remelted from a single primary melt.

11. Product Analysis

11.1 The purchaser may make a product analysis on forgings supplied to this specification. Samples for analysis shall be taken from midway between the center and surface of solid forgings, midway between the inner and outer surfaces of hollow forgings, midway between the center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 2 with the tolerances as stated in Table 4 or Table 5.

12. Retreatment

12.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings and repeat the tests specified in Section 7.

13. Workmanship, Finish, and Appearance

13.1 The forgings shall be free of scale, machining burrs which might hinder fit-up, and other injurious imperfections as defined herein. The forgings shall have a workmanlike finish and machined surfaces (other than surfaces having special requirements) shall have a surface finish not to exceed 250 AA (arithmetic average) roughness height.

13.2 At the discretion of the inspector representing the purchaser, finished forgings shall be subject to rejection if surface imperfections acceptable under 13.4 are not scattered but appear over a large area in excess of what is considered to be a workmanlike finish.

13.3 *Depth of Injurious Imperfections* — Linear imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness of the finished forging, such imperfections shall be considered injurious.

13.4 *Machining or Grinding Imperfections Not Classified as Injurious* — Surface imperfections not classified as injurious shall be treated as follows:

13.4.1 Seams, laps, tears, or slivers not deeper than 5% of the nominal wall thickness or $\frac{1}{16}$ in. [1.6 mm], whichever is less, need not be removed. If these imperfections are removed, they shall be removed by machining or grinding.

13.4.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed the limitations set forth in 13.4.1. Imperfections that are deeper than $\frac{1}{16}$ in. [1.6 mm], but which do not encroach on the minimum wall thickness of the forging shall be removed by grinding to sound metal.

13.4.3 When imperfections have been removed by grinding or machining, the outside dimension at the point of grinding or machining may be reduced by the amount removed. Should it be impracticable to secure a direct measurement, the wall thickness at the point of grinding, or at an imperfection not required to be removed, shall be determined by deducting the amount removed by grinding from the nominal finished wall thickness of the forging, and the remainder shall be not less than the minimum specified or required wall thickness.

14. Repair by Welding

14.1 Weld repairs shall be permitted (see Supplementary Requirement S7) at the discretion of the manufacturer with the following limitations and requirements:

14.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

98 **14.1.2** The weld metal shall be deposited using the electrodes specified in Table 6 except as otherwise provided in Supplementary Requirement S11. The electrodes shall be purchased in accordance with ASME Specification SFA-5.4, SFA-5.5, SFA-5.9 or SFA-5.11. The submerged arc process with neutral flux, the gas metal-arc welding process, the gas tungsten-arc processes, and gas shielded processes using flux-core consumables, may be used.

14.1.3 Defects shall be completely removed prior to welding by chipping or grinding to sound metal as verified by magnetic particle inspection in accordance with Test Method A 275/A 275M for the low alloy steels and ferritic, martensitic, or ferritic-austenitic stainless steels, or by liquid penetrant inspection in accordance with Practice E 165 for all grades.

14.1.4 After repair welding, the welded area shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic-particle or liquid-penetrant inspection, as applicable.

14.1.5 The preheat, interpass temperature, and post-weld heat treatment requirements given in Table 6 shall be met. Austenitic stainless steel forgings may be repair-welded without the post-weld heat treatment of Table 6, provided purchaser approval is obtained prior to repair.

14.1.6 Repair by welding shall not exceed 10% of the surface area of the forging nor $33\frac{1}{3}$% of the wall thickness of the finished forging or $\frac{3}{8}$ in. [9.5 mm], whichever is less without prior approval of the purchaser.

14.1.7 When approval of the purchaser is obtained, the limitations set forth in 14.1.6 may be exceeded, but all other requirements of Section 14 shall apply.

14.1.8 No weld repairs are permitted for F 6a Classes 3 and 4.

15. Inspection

15.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with the purchase order. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture unless otherwise agreed upon.

16. Rejection

16.1 Each forging that develops injurious defects during shop working operations or in service shall be rejected and the manufacturer notified.

16.2 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

17. Certification

17.1 For forgings made to specified dimensions, when agreed upon by the purchaser, and for forgings made to dimensional standards, the application of identification marks as required in 18.1 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification.

17.2 Test reports, when required, shall include certification that all requirements of this specification have been met. The specification designation included on test reports shall include year of issue and revision letter, if any. The manufacturer shall provide the following where applicable:

17.2.1 Type heat treatment, Section 5.

17.2.2 Product analysis results, Section 11 (Tables 2, 4, and 5).

17.2.3 Tensile property results, Section 7 (Table 3), report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent.

17.2.4 Chemical analysis results, Section 6 (Table 2).

17.2.5 Hardness results, Section 7 (Table 3).

17.2.6 Grain size results, Section 8, and

17.2.7 Any supplementary testing required by the purchase order.

18. Product Marking

18.1 Identification marks consisting of the manufacturer's symbol or name (Note 3), the heat number or

manufacturer's heat identification, designation of service rating, the specification number, the designation, F1, F2, etc., showing the grade of material, and the size shall be legibly stamped on each forging or the forgings may be marked in accordance with Standard SP 25 of the Manufacturer's Standardization Society of the Valve and Fittings Industry, and in such position so as not to injure the usefulness of the forging. The specification number marked on the forgings need not include specification year of issue and revision letter.

NOTE 3 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

18.1.1 Quenched and tempered low alloy or martensitic stainless forgings shall be stamped with the letters QT following the specification designation.

18.1.2 Forgings repaired by welding shall be marked with the letter "W" following the Specification designation. When repair-welded austenitic stainless steel forgings have not been postweld heat treated in accordance with Table 6, the letters "WNS" shall be marked following the specification designation.

18.1.3 When test reports are required, the markings shall consist of the manufacturer's symbol or name, the grade symbol, and such other markings as necessary to identify the part with the test report (18.1.1 and 18.1.2 shall apply).

18.1.4 Parts meeting all requirements for more than one class or grade may be marked with more than one class or grade designation such as F 304/F 304H, F 304/F 304L, etc.

18.2 *Bar Coding* — In addition to the requirements in 18.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 austenitic stainless steel; chromium alloy steel; chromium-molybdenum steel; ferritic/austenitic stainless steel; ferritic stainless steel; martensitic stainless steel; nickel alloy steel; notch toughness requirement; pipe fittings, steel; piping applications; pressure containing parts; stainless steel fittings; stainless steel forgings; steel flanges; steel forgings, alloy; steel valves; temperature service applications, elevated; temperature service application, high; wrought material

98

TABLE 1
HEAT TREATING REQUIREMENTS

Grade	Heat Treat Type	Austenitizing/ Solutioning Temperature, min °F (°C) [Notes (1), (4)]	Cooling Media	Quenching Cool Below °F (°C)	Tempering Temperature, min °F (°C)
		Low Alloy Steels			
F 1	anneal	1650 [900]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1650 [900]	air cool	[Note (2)]	1150 [620]
F 2	anneal	1650 [900]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1650 [900]	air cool	[Note (2)]	1150 [620]
F 5, F 5a	anneal	1750 [955]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1750 [955]	air cool	[Note (2)]	1250 [675]
F 9	anneal	1750 [955]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1750 [955]	air cool	[Note (2)]	1250 [675]
F 91	normalize and temper	1900–2000 [1040–1095]	air cool	[Note (2)]	1350 [730]
F 11, Class 1, 2 and 3	anneal	1650 [900]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1650 [900]	air cool	[Note (2)]	1150 [620]
F 12, Class 1 and 2	anneal	1650 [900]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1650 [900]	air cool	[Note (2)]	1150 [620]
F 21, F 3V, and F 3VCb	anneal	1750 [955]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1750 [955]	air cool	[Note (2)]	1250 [675]
F 22, Class 1 and 3	anneal	1650 [900]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1650 [900]	air cool	[Note (2)]	1250 [675]
FR	anneal	1750 [955]	furnace cool	[Note (2)]	[Note (2)]
	normalize	1750 [955]	air cool	[Note (2)]	[Note (2)]
	normalize and temper	1750 [955]	air cool	[Note (2)]	1250 [675]
		Martensitic Stainless Steels			
F 6a Class 1	anneal	not specified	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	not specified	air cool	400 [205]	1325 [725]
	temper	not required	[Note (2)]	[Note (2)]	1325 [725]
F 6a Class 2	anneal	not specified	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	not specified	air cool	400 [205]	1250 [675]
	temper	not required	[Note (2)]	[Note (2)]	1250 [675]
F 6a Class 3	anneal	not specified	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	not specified	air cool	400 [205]	1100 [595]
F 6a Class 4	anneal	not specified	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	not specified	air cool	400 [205]	1000 [540]
F 6b	anneal	1750 [955]	furnace cool	[Note (2)]	[Note (2)]
	normalize and temper	1750 [955]	air cool	400 [205]	1150 [620]
F 6NM	normalize and temper	1850 [1010]	air cool	200 [95]	1040–1120 [560–600]
		Ferritic Stainless Steels			
F XM-27Cb	anneal	1850 [1010]	furnace cool	[Note (2)]	[Note (2)]
F 429	anneal	1850 [1010]	furnace cool	[Note (2)]	[Note (2)]
F 430	anneal	not specified	furnace cool	[Note (2)]	[Note (2)]

TABLE 1 (CONT'D)
HEAT TREATING REQUIREMENTS

98

Grade	Heat Treat Type	Austenitizing/ Solutioning Temperature, min °F (°C) [Notes (1), (4)]	Cooling Media	Quenching Cool Below °F (°C)	Tempering Temperature, min °F (°C)
		Austenitic Stainless Steels			
F 304	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 304H	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 304L	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 304N	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 304LN	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 310	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 316	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 316H	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 316L	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 316N	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 316LN	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 317	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 317L	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 347	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 347H	solution treat and quench	1925 [1050]	liquid	500 [260]	[Note (2)]
F 348	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 348H	solution treat and quench	2000 [1000]	liquid	500 [260]	[Note (2)]
F 321	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 321H	solution treat and quench	1925 [1050]	liquid	500 [260]	[Note (2)]
F XM-11	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F XM-19	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 10	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 44	solution treat and quench	2100 [1150]	liquid	500 [260]	[Note (2)]
F 45	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 46	solution treat and quench	2010–2140 [1100–1140]	liquid	500 [260]	[Note (2)]
F 47	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 48	solution treat and quench	1900 [1040]	liquid	500 [260]	[Note (2)]
F 49	solution treat and quench	2050 [1120]	liquid	500 [260]	[Note (2)]
F 56	solution treat and quench	2050–2160 [1120–1180]	liquid	500 [260]	[Note (2)]
		Ferritic-Austenitic Stainless Steels			
F 50	solution treat and quench	1925 [1050]	liquid	500 [260]	[Note (2)]
F 51	solution treat and quench	1870 [1020]	liquid	500 [260]	[Note (2)]
F 52 [Note (3)]	...	...	...	...	...
F 53	solution treat and quench	1880 [1025]	liquid	500 [260]	[Note (2)]
F 54	solution treat and quench	1920–2060 [1050–1125]	liquid	500 [260]	[Note (2)]
F 55	solution treat and quench	2010–2085 [1100–1140]	liquid	500 [260]	[Note (2)]
F 57	solution treat and quench	1940 [1060]	liquid	175 [80]	[Note (2)]

NOTES:
(1) Minimum unless temperature range is listed.
(2) Not applicable.
(3) Grade F 52 shall be solution treated at 1825 to 1875°F [995 to 1025°C] 30 min/in. of thickness and water quenched.
(4) For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments.

TABLE 2
CHEMICAL REQUIREMENTS

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium plus Tantalum	Tantalum, max	Titanium
							Low Alloy Steels						
F 1	K12822	carbon-molybdenum	0.28 max	0.60–0.90	0.045	0.045	0.15–0.35	. . .	. . .	0.44–0.65	. . .	. . .	. . .
F 2[A]	K12122	0.5% chromium, 0.5% molybdenum	0.05–0.21	0.30–0.80	0.040	0.040	0.10–0.60	. . .	0.50–0.81	0.44–0.65	. . .	. . .	. . .
F 5[B]	K41545	4 to 6% chromium	0.15 max	0.30–0.60	0.030	0.030	0.50 max	0.50 max	4.0–6.0	0.44–0.65	. . .	. . .	. . .
F 5a[B]	K42544	4 to 6% chromium	0.25 max	0.60 max	0.040	0.030	0.50 max	0.50 max	4.0–6.0	0.44–0.65	. . .	. . .	. . .
F 9	K90941	9% chromium	0.15 max	0.30–0.60	0.030	0.030	0.50–1.00	. . .	8.0–10.0	0.90–1.10	. . .	. . .	. . .
F 91		9% chromium, 1% molybdenum, 0.2% vanadium plus columbium and nitrogen	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	0.40 max	8.0–9.50	0.85–1.05	Other Elements Cb 0.06–0.10 N 0.03–0.07 Al 0.04 max V 0.18–0.25		
F 11 Class 1	K11597	1.25% chromium, 0.5% molybdenum	0.05–0.15	0.30–0.60	0.030	0.030	0.50–1.00	. . .	1.00–1.50	0.44–0.65	. . .	. . .	. . .
F 11 Class 2	K11572	1.25% chromium, 0.5% molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00	. . .	1.00–1.50	0.44–0.65	. . .	. . .	. . .
F 11 Class 3	K11572	1.25% chromium, 0.5% molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00	. . .	1.00–1.50	0.44–0.65	. . .	. . .	. . .
F 12 Class 1	K11562	1% chromium, 0.5% molybdenum	0.05–0.15	0.30–0.60	0.045	0.045	0.50 max	. . .	0.80–1.25	0.44–0.65	. . .	. . .	. . .
F 12 Class 2	K11564	1% chromium, 0.5% molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.10–0.60	. . .	0.80–1.25	0.44–0.65	. . .	. . .	. . .
F 21	K31545	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	. . .	2.7–3.3	0.80–1.06	. . .	. . .	. . .
F 3V	K31830	3% chromium, 1% molybdenum, 0.25% vanadium plus boron and titanium	0.05–0.18	0.30–0.60	0.020	0.020	0.10 max	. . .	2.8–3.2	0.90–1.10	Other Elements V 0.20–0.30 B 0.001–0.003		0.015–0.035
F 3VCb	. . .	. . .	0.10–0.15	0.30–0.60	0.020	0.010	0.10 max	0.25 max	2.7–3.3	0.90–1.10	Other Elements V 0.20–0.30 Cb 0.015–0.070 Cu 0.25 max Ca 0.0005–0.0150		0.015 max
F 22 Class 1	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	. . .	2.00–2.50	0.87–1.13	. . .	. . .	. . .
F 22 Class 3	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	. . .	2.00–2.50	0.87–1.13	. . .	. . .	. . .
F 22V	K31835	2.25% chromium, 1% molybdenum, 0.25% vanadium	0.11–0.15	0.30–0.60	0.015	0.010	0.10 max	0.25 max	2.00–2.50	0.90–1.10	Other Elements Cu 0.20 max V 0.25–0.35 Cb 0.07 max B 0.002 max Ca 0.015 max[J]		0.030 max
FR	K22035	2% nickel, 1% copper	0.20 max	0.40–1.06	0.045	0.050	. . .	1.60–2.24	. . .	. . .	Other Elements Cu 0.75–1.25		

TABLE 2 (CONT'D)
CHEMICAL REQUIREMENTS

Martensitic Stainless Steels													
F 6a	S41000	13% chromium	0.15 max	1.00 max	0.040	0.030	1.00 max	0.50 max	11.5–13.5	...	...	...	...
F 6b	S41026	13% chromium, 0.5% molybdenum	0.15 max	1.00 max	0.02	0.02	1.0 max	1.0–2.0	11.5–13.5	0.40–0.60	Other Elements Cu 0.50 max		
F 6NM	S41500	13% chromium, 4% nickel	0.05 max	0.5–1.0	0.030	0.030	0.60 max	3.5–5.5	11.5–14.0	0.5–1.0	...	...	...
Ferritic Stainless Steels													
F XM-27Cb[C]	S44627	27 chromium, 1 molybdenum	0.010 max	0.40 max	0.020	0.020	0.40 max	0.50 max	25.0–27.5	0.75–1.50	Other Elements N 0.015 max Cu 0.20 max Cb 0.05–0.20		
F 429	S42900	15 chromium	0.12 max	1.00 max	0.040	0.030	0.75 max	0.50 max	14.0–16.0	...	...	...	...
F 430	S43000	17 chromium	0.12 max	1.00 max	0.040	0.030	0.75 max	0.50 max	16.0–18.0	...	...	...	...
Austenitic Stainless Steels													
F 304[I]	S30400	18 chromium, 8 nickel	0.08 max	2.00 max	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	...	...	...	...
F 304H	S30409	18 chromium, 8 nickel	0.04–0.10	2.00 max	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	...	...	...	...
F 304L[I]	S30403	18 chromium, 8 nickel, low carbon	0.035 max	2.00 max	0.045	0.030	1.00 max	8.0–13.0	18.0–20.0	...	...	...	...
F 304N[D]	S30451	18 chromium, 8 nickel, modified with nitrogen	0.08 max	2.00 max	0.045	0.030	0.75 max	8.0–10.5	18.0–20.0	...	...	...	...
F 304LN[D]	S30453	18 chromium, 8 nickel, modified with nitrogen	0.030 max	2.00 max	0.045	0.030	0.75 max	8.0–10.5	18.0–20.0	...	...	...	...
F 310	S31000	25 chromium, 20 nickel	0.15 max	2.00 max	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	...	...	...	...
F 316[I]	S31600	18 chromium, 8 nickel, modified with molybdenum	0.08 max	2.00 max	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F 316H	S31609	18 chromium, 8 nickel, modified with molybdenum	0.04–0.10	2.00 max	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F 316L[I]	S31603	18 chromium, 8 nickel, modified with molybdenum, low carbon	0.035 max	2.00 max	0.045	0.030	1.00 max	10.0–15.0	16.0–18.0	2.00–3.00	...	...	...
F 316N[D]	S31651	18 chromium, 8 nickel, modified with molybdenum and nitrogen	0.08 max	2.00 max	0.045	0.030	0.75 max	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F316LN[D]	S31653	18 chromium, 8 nickel, modified with molybdenum and nitrogen	0.030 max	2.00 max	0.045	0.030	0.75 max	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...
F 317	S31700	19 chromium, 13 nickel, 3.5 molybdenum	0.08 max	2.00 max	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
F 317L	S31703	19 chromium, 13 nickel, 3.5 molybdenum	0.03 max	2.00 max	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	...	...	...
F 321	S32100	18 chromium, 8 nickel modified with titanium	0.08 max	2.00 max	0.045	0.030	1.00 max	9.0–12.0	17.0 min	...	...	...	[E]
F 321H	S32109	18 chromium, 8 nickel, modified with titanium	0.04–0.10	2.00 max	0.045	0.030	1.00 max	9.0–12.0	17.0 min	...	...	...	[F]
F 347	S34700	18 chromium, 8 nickel modified with columbium	0.08 max	2.00 max	0.045	0.030	1.00 max	9.0–13.0	17.0–20.0	...	[G]	...	...
F 347H	S34709	18 chromium, 8 nickel, modified with columbium	0.04–0.10	2.00 max	0.045	0.030	1.00 max	9.0–13.0	17.0–20.0	...	[H]	...	...
F 348	S34800	18 chromium, 8 nickel modified with columbium	0.08 max	2.00 max	0.045	0.030	1.00 max	9.0–13.0	17.0–20.0	...	[G]	0.10	...

TABLE 2 (CONT'D)
CHEMICAL REQUIREMENTS

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium plus Tantalum	Tantalum, max	Titanium
						Austenitic Stainless Steels							
F 348H	S34809	18 chromium, 8 nickel, modified with columbium	0.04–0.10	2.00 max	0.045	0.030	1.00 max	9.0–13.0	17.0–20.0	. . .	[H]	0.10	. . .
F XM-11	S21904	20 chromium, 6 nickel, 9 manganese	0.040 max	8.0–10.0	0.060	0.030	1.00 max	5.5–7.5	19.0–21.5	. . .	. . .	Other Elements N 0.15–0.40	
F XM-19	S20910	22 chromium, 13 nickel, 5 manganese	0.06 max	4.0–6.0	0.040	0.030	1.00 max	11.5–13.5	20.5–23.5	1.50–3.0	0.10–0.30	Other Elements N 0.20–0.40 V 0.10–0.30	
F 10	S33100	20 nickel, 8 chromium	0.10–0.20	0.50–0.80	0.040	0.030	1.00–1.40	19.0–22.0	7.0–9.0	. . .	. . .	. . .	. . .
F 44	S31254	20 chromium, 18 nickel, 6 molybdenum, low carbon	0.020 max	1.00 max	0.030	0.010	0.80 max	17.5–18.5	19.5–20.5	6.0–6.5	. . .	Other Elements Cu 0.50–1.00 N 0.18–0.22	
F 45	S30815	21 chromium, 11 nickel modified with nitrogen and cerium	0.05–0.10	0.80 max	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	. . .	. . .	Other elements N 0.14–0.20 Ce 0.03–0.08	
F 46	S30600	18 chromium, 15 nickel, 4 silicon	0.018 max	2.00 max	0.020	0.020	3.7–4.3	14.0–15.5	17.0–18.5	0.20 max	. . .	. . .	
F 47	S31725	19 chromium, 15 nickel, 4 molybdenum	0.030 max	2.00 max	0.045	0.030	0.75 max	13.0–17.5	18.0–20.0	4.0–5.0	. . .	Other Elements N 0.10 max	
F 48	S31726	19 chromium, 15 nickel, 4 molybdenum	0.030 max	2.00 max	0.045	0.030	0.75 max	13.5–17.5	17.0–20.0	4.0–5.0	. . .	Other Elements N 0.10–0.20	
F 49	S34565	24 chromium, 17 nickel, 6 manganese, 5 molybdenum	0.030 max	5.0–7.0	0.030	0.010	1.00 max	16.0–18.0	23.0–25.0	4.0–5.0	0.1	Other Elements N 0.4–0.6	
F 56	S33228	32 nickel, 27 chromium, with columbium	0.04–0.08	1.00 max	0.020	0.015	0.30 max	31.0–33.0	26.0–28.0	. . .	0.6–1.0	Other Elements Ce 0.05–0.10 Al 0.025	
						Ferritic-Austenitic Stainless Steels							
F 50	S31200	25 chromium, 6 nickel, modified with nitrogen	0.030 max	2.00 max	0.045	0.030	1.00 max	5.5–6.5	24.0–26.0	1.2–2.0	. . .	Other Elements N 0.14–0.20	
F 51	S31803	22 chromium, 5.5 nickel, modified with nitrogen	0.030 max	2.00 max	0.030	0.020	1.00 max	4.5–6.5	21.0–23.0	2.5–3.5	. . .	Other Elements N 0.08–0.20	
F 52	S32950	26 chromium, 3.5 nickel, 1.0 molybdenum	0.03 max	2.00 max	0.035	0.010	0.60 max	3.5–5.2	26.0–29.0	1.00–2.50	. . .	Other Elements N 0.15–0.35	
F 53	S32750	25 chromium, 7 nickel, 4 molybdenum, modified with nitrogen	0.030 max	1.2 max	0.035	0.020	0.8 max	6.0–8.0	24.0–26.0	3.0–5.0	. . .	Other Elements N 0.24–0.32 Cu 0.5 max	

TABLE 2 (CONT'D)
CHEMICAL REQUIREMENTS

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium plus Tantalum	Tantalum, max	Titanium
			Ferritic-Austenitic Stainless Steels										
F 54	S32740	25 chromium, 7 nickel, modified with nitrogen and tungsten	0.030 max	1.0 max	0.030 max	0.020 max	0.80 max	6.0–8.0	24.0–26.0	2.50–3.50	. . .	Other Elements N 0.24–0.32 Cu 0.20–0.80 W 1.50–2.50	
F 55	S32760	25 chromium, 7 nickel, 3.5 molybdenum, modified with nitrogen and tungsten	0.030 max	1.00 max	0.030	0.010	1.00 max	6.00–8.00	24.00–26.00	3.00–4.00	. . .	Other Elements N 0.20–0.30 Cu 0.50–1.00 W 0.50–1.00 [K]	
F 57	S39277	26 chromium, 7 nickel, 3.7 molybdenum	0.025 max	0.80 max	0.025	0.002	0.80 max	6.5–8.0	24.0–26.0	3.0–4.0	. . .	Other Elements Cu 1.20–2.00 W 0.80–1.20 N 0.23–0.33	

NOTES:
[A] Grade F 2 was formerly assigned to the 1% chromium, 0.5% molybdenum grade which is now Grade F 12.
[B] The present grade F 5a (0.25 max carbon) previous to 1955 was assigned the identification symbol F 5. Identification symbol F 5 in 1955 was assigned to the 0.15 max carbon grade to be consistent with ASTM specifications for other products such as pipe, tubing, bolting, welding fittings, etc.
[C] Grade F XM-27Cb shall have a nickel plus copper content of 0.50 max %. Product analysis tolerance over the maximum specified limit for carbon and nitrogen shall be 0.002%.
[D] Grades F 304N, F 316N, F 304LN, and F 316LN shall have a nitrogen content of 0.10 to 0.16%.
[E] Grade F 321 shall have a titanium content of not less than five times the carbon content and not more than 0.70%.
[F] Grade F 321H shall have a titanium content of not less than 4 times the carbon content and not more than 0.70%.
[G] Grades F 347 and F 348 shall have a columbium plus tantalum content of not less than ten times the carbon content and not more than 1.10%.
[H] Grades F 347H and F 348H shall have a columbium plus tantalum content of not less than 8 times the carbon content and not more than 1.10%.
[I] Grades F 304, F 304L, F 316, and F 316L shall have a maximum nitrogen content of 0.10%.
[J] For Grade F 22V, rare earth metals (REM) may be added in place of calcium, subject to agreement between the producer and the purchaser. In that case the total amount of REM shall be determined and reported.
[K] % Cr + 3.3 × % Mo + 16 × % N = 40 min.

98

TABLE 3
TENSILE AND HARDNESS REQUIREMENTS

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa] [Note (1)]	Elongation in 2 in. [50 mm] or 4*D*, min, %	Reduction of Area min, %	Brinell Hardness Number
Low Alloy Steels:					
F 1	70 [485]	40 [275]	20.0	30.0	143–192
F 2	70 [485]	40 [275]	20.0	30.0	143–192
F 5	70 [485]	40 [275]	20.0	35.0	143–217
F 5a	90 [620]	65 [450]	22.0	50.0	187–248
F 9	85 [585]	55 [380]	20.0	40.0	179–217
F 91	85 [585]	60 [415]	20.0	40.0	248 max
F 11 Class 1	60 [415]	30 [205]	20.0	45.0	121–174
F 11 Class 2	70 [485]	40 [275]	20.0	30.0	143–207
F 11 Class 3	75 [515]	45 [310]	20.0	30.0	156–207
F 12 Class 1	60 [415]	32 [220]	20.0	45.0	121–174
F 12 Class 2	70 [485]	40 [275]	20.0	30.0	143–207
F 21	75 [515]	43 [310]	20.0	30.0	156–207
F 3V, and F 3VCb	85–110 [585–760]	60 [415]	18.0	45.0	174–237
F 22 Class 1	60 [415]	30 [205]	20.0	35.0	170 max
F 22 Class 3	75 [515]	45 [310]	20.0	30.0	156–207
F 22V	85–110 [585–780]	60 [415]	18.0	45.0	174–237
FR	63 [435]	46 [315]	25.0	38.0	197 max
Martensitic Stainless Steels:					
F 6a Class 1	70 [485]	40 [275]	18.0	35.0	143–187
F 6a Class 2	85 [585]	55 [380]	18.0	35.0	167–229
F 6a Class 3	110 [760]	85 [585]	15.0	35.0	235–302
F 6a Class 4	130 [895]	110 [760]	12.0	35.0	263–321
F 6b	110–135 [760–930]	90 [620]	16.0	45.0	235–285
F 6NM	115 [790]	90 [620]	15.0	45.0	295 max
Ferritic Stainless Steels:					
F XM-27Cb	60 [415]	35 [240]	20.0	45.0	190 max
F 429	60 [415]	35 [240]	20.0	45.0	190 max
F 430	60 [415]	35 [240]	20.0	45.0	190 max
Austenitic Stainless Steels:					
F 304	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 304H	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 304L	70 [485] [Note (3)]	25 [170]	30.0	50.0	. . .
F 304N	80 [550]	35 [240]	30.0 [Note (4)]	50.0 [Note (5)]	. . .
F 304LN	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 310	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 316	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 316H	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 316L	70 [485] [Note (3)]	25 [170]	30.0	50.0	. . .
F 316N	80 [550]	35 [240]	30.0 [Note (4)]	50.0 [Note (5)]	. . .
F 316LN	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 317	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 317L	70 [485] [Note (3)]	25 [170]	30.0	50.0	. . .
F 347	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 347H	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 348	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 348H	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 321	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .
F 321H	75 [515] [Note (2)]	30 [205]	30.0	50.0	. . .

TABLE 3 (CONT'D)
TENSILE AND HARDNESS REQUIREMENTS

98

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa] [Note (1)]	Elongation in 2 in. [50 mm] or 4*D*, min, %	Reduction of Area min, %	Brinell Hardness Number
Austenitic Stainless Steels:					
F XM-11	90 [620]	50 [345]	45.0	60.0	...
F XM-19	100 [690]	55 [380]	35.0	55.0	...
F 10	80 [550]	30 [205]	30.0	50.0	...
F 44	94 [650]	44 [300]	35.0	50.0	...
F 45	87 [600]	45 [310]	40.0	50.0	...
F 46	78 [540]	35 [240]	40.0	50.0	...
F 47	75 [525]	30 [205]	40.0	50.0	...
F 48	80 [550]	35 [240]	40.0	50.0	...
F 49	115 [795]	60 [415]	35.0	40.0	...
F 56	73 [500]	27 [185]	30	35	...
Ferritic-Austenitic Stainless Steels:					
F 50	100–130 [690–900]	65 [450]	25.0	50.0	...
F 51	90 [620]	65 [450]	25.0	45.0	...
F 52	100 [690]	70 [485]	15.0	...	...
F 53	116 [800] [Note (6)]	80 [550] [Note (6)]	15.0	...	310 max
F 54	116 [800]	80 [550]	15.0	30.0	310 max
F 55	109–130 [750–895]	80 [550]	25.0	45.0	...
F 57	118 [820]	85 [585]	25.0	50.0	...

NOTES:
(1) Determined by the 0.2% offset method. For ferritic steels only, the 0.5% extension-under-load method may also be used.
(2) For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 70 ksi [485 MPa].
(3) For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 65 ksi [450 MPa].
(4) Longitudinal. The transverse elongation shall be 25% in 2 in. or 50 mm, min.
(5) Longitudinal. The transverse reduction of area shall be 45% min.
(6) For sections over 2 in. [50 mm] in thickness, the minimum tensile strength shall be 109 ksi [750 MPa]; the minimum yield strength shall be 75 ksi [515 MPa].

TABLE 4
PRODUCT ANALYSIS TOLERANCES FOR LOW ALLOY STEELS WITH A MAXIMUM CHROMIUM LIMIT OF 4% OR MORE AND STAINLESS STEELS[A]

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	0.030, incl	0.005
	over 0.030 to 0.20 incl	0.01
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
	over 3.00 to 6.00	0.05
	over 6.00 to 10.00	0.06
Phosphorus	to 0.040, incl	0.005
Sulfur	to 0.030, incl	0.005
Silicon	to 1.00, incl	0.05
	over 1.00 to 5.00, incl	0.10
Chromium	over 4.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
	over 15.00 to 20.00, incl	0.20
	over 20.00 to 27.50, incl	0.25
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
	over 20.00 to 22.00, incl	0.20
Molybdenum	to 0.20 incl	0.01
	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
	over 2.00 to 7.00, incl	0.10
Titanium	all ranges	0.05
Columbium-tantalum	all ranges	0.05
Tantalum	to 0.10, incl	0.02
Cobalt	0.05 to 0.20, incl	0.01[B]
Nitrogen	to 0.19 incl	0.01
	over 0.19 to 0.25	0.02
	over 0.25 to 0.35	0.03
	over 0.35 to 0.45	0.04
	over 0.45 to 0.60	0.05
Columbium	0.05 to 0.20, incl	0.01
Aluminum	to 0.05 incl	0.01
Vanadium	to 0.10 incl	0.01
	over 0.10 to 0.25 incl	0.02
Cerium	0.03 to 0.08	−0.005 +0.01
Tungsten	to 1.00, incl	0.04
Copper	to 1.00, incl	0.03

NOTES:
[A] This table does not apply to heat analysis.
[B] Product analysis limits for cobalt under 0.05% have not been established and the producer should be consulted for those limits.

TABLE 5
PRODUCT ANALYSIS TOLERANCES FOR LOW-ALLOY STEELS WITH MAXIMUM CHROMIUM LIMIT LESS THAN 4%

Element[B]	Limit or Maximum of Specified Range, %	Tolerance Over Maximum Limit or Under Minimum Limit for Size Ranges Shown, %[A]			
		100 in.^{2} (6.45 × 10^4 mm^2), or less	Over 100 to 200 in.^{2} (1.290 × 10^5 mm^2), incl	Over 200 to 400 in.^{2} (2.581 × 10^5 mm^2), incl	Over 400 in.^{2}
Manganese	to 0.90 incl	0.03	0.04	0.05	0.06
	over 0.90 to 1.00 incl	0.04	0.05	0.06	0.07
Phosphorus	to 0.045 incl	0.005	0.010	0.010	0.010
Sulfur	to 0.045 incl	0.005	0.010	0.010	0.010
Silicon	to 0.40 incl	0.02	0.02	0.03	0.04
	over 0.40 to 1.00 incl	0.05	0.06	0.06	0.07
Nickel	to 0.50	0.03	0.03	0.03	0.03
Chromium	to 0.90 incl	0.03	0.04	0.04	0.05
	over 0.90 to 2.10 incl	0.05	0.06	0.06	0.07
	over 2.10 to 3.99 incl	0.10	0.10	0.12	0.14
Molybdenum	to 0.20 incl	0.01	0.01	0.02	0.03
	over 0.20 to 0.40 incl	0.02	0.03	0.03	0.04
	over 0.40 to 1.15 incl	0.03	0.04	0.05	0.06
Copper	to 1.00 incl	0.03	0.03	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05	0.05	0.05
Titanium	to 0.10	0.01	0.01	0.01	0.01
Vanadium	to 0.10 incl	0.01	0.01	0.01	0.01
	0.11 to 0.25 incl	0.02	0.02	0.02	0.02
	0.26 to 0.50 incl	0.03	0.03	0.03	0.03

NOTES:
[A] Cross-sectional area.
[B] Product analysis for carbon boron, columbium and calcium shall conform to Table 2.

TABLE 6
REPAIR WELDING REQUIREMENTS

Grade Symbol	Electrodes[A]	Recommended Preheat and Interpass Temperature Range, °F [°C]	Minimum Post Weld Heat-Treatment Temperature °F [°C]
	Low Alloy Steels		
F 1	E 7018-A 1	200–400 [95–205]	1150 [620]
F 2	E 8018-B 1	300–600 [150–315]	1150 [620]
F 5	E 502-15 or 16	400–700 [205–370]	1250 [675]
F 5a	E 502-15 or 16	400–700 [205–370]	1250 [675]
F 9	E 505-15 or 16	400–700 [205–370]	1250 [675]
F 91	9% Cr, 1% Mo, VCbN	400–700 [205–370]	1300 [705]
F 11, Class 1, 2, and 3	E 8018-B 2	300–600 [150–315]	1150 [620]
F 12, Class 1 and 2	E 8018-B 2	300–600 [150–315]	1150 [620]
F 21	E 9018-B 3	300–600 [150–315]	1250 [675]
F 3V, and F 3VCb	3% Cr, 1% Mo, ¼% V-Ti	300–600 [150–315]	1250 [675]
F 22 Class 1	E 9018-B 3	300–600 [150–315]	1250 [675]
F 22 Class 3	E 9018-B 3	300–600 [150–315]	1250 [675]
F 22V	2.25% Cr, 1% Mo, 0.25% V-Cb	300–600 [150–315]	1250 [675]
	Martensitic Stainless Steels		
F 6a, Class 1	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6a, Class 2	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6b	13% Cr, 1½% Ni, ½% Mo	400–700 [205–370]	1150 [620]
F 6NM	13% Cr, 4% Ni	300–700 [150–370]	1050 [565]
	Ferritic Stainless Steels		
F XM-27Cb	26% Cr, 1% Mo	NR[B]	NR
F 429	E 430-16	400–700 [205–370]	1400 [760]
F 430	E 430-16	NR	1400 [760]
FR	E 8018-C2	NR	NR
	Austenitic Stainless Steels		
F 304	E 308-15 or 16	NR	1900 [1040] + WQ[C]
F 304L	E 308L-15 to 16	NR	1900 [1040] + WQ
F 304H	E 308-15 or 16	NR	1900 [1040] + WQ
F 304N	E 308-15 or 16	NR	1900 [1040] + WQ
F 304LN	E 308L-15 or 16	NR	1900 [1040] + WQ
F 310	E 310-15 or 16	NR	1900 [1040] + WQ
F 316	E 316-15 or 16	NR	1900 [1040] + WQ
F 316L	E 316L-15 or 16	NR	1900 [1040] + WQ
F 316H	E 316-15 or 16	NR	1900 [1040] + WQ
F 316N	E 316-15 or 16	NR	1900 [1040] + WQ
F 316LN	E 316L-15 or 16	NR	1900 [1040] + WQ
F 317	E 317-15 or 16	NR	1900 [1040] + WQ
F 317L	E 317L-15 or 16	NR	1900 [1040] + WQ
F 321[D]	E 347-15 or 16	NR	1900 [1040] + WQ
F 321H[D]	E 347-15 or 16	NR	1925 [1050] + WQ
F 347	E 347-15 or 16	NR	1900 [1040] + WQ
F 347H	E 347-15 or 16	NR	1925 [1050] + WQ
F 348	E 347-15 or 16	NR	1900 [1040] + WQ
F 348H	E 347-15 or 16	NR	1925 [1050] + WQ
F XM-11	XM-10W	NR	NR
F XM-19	XM-19W	NR	NR
F 10[D]	. . .	. . .	. . .
F 44	E NiCrMo-3	NR	2100 [1150] + WQ
F 45[D]	. . .	. . .	. . .

TABLE 6 (CONT'D)
REPAIR WELDING REQUIREMENTS

Grade Symbol	Electrodes[A]	Recommended Preheat and Interpass Temperature Range, °F [°C]	Minimum Post Weld Heat-Treatment Temperature °F [°C]
	Austenitic Stainless Steels		
F 46	. . .	. . .	. . .
F 47	. . .[E]	. . .	2100 [1150] + WQ
F 48	. . .[E]	. . .	2100 [1150] + WQ
F 49	. . .[E]	. . .	2100 [1150] + WQ
	Ferritic-Austenitic Stainless Steels		
F 50	25% Cr, 6% Ni, 1.7% Mo	NR	NR
F 51	22% Cr, 5.5% Ni, 3% Mo	NR	NR
F 52	26% Cr, 8% Ni, 2% Mo	NR	NR
F 53	25% Cr, 7% Ni, 4% Mo	NR	NR
F 54	25% Cr, 7% Ni, 3% Mo, W	NR	NR
F 55	25% Cr, 7% Ni, 3.5% Mo	NR	NR
F 57	25% Cr, 7% Ni, 3% Mo, 1.5% Cu, 1% W	NR	NR

NOTES:
[A] Electrodes shall comply with ASME SFA 5.4, SFA 5.5, and corresponding ER grades of SFA-5.9 or SFA-5.11.
[B] NR = not required.
[C] WQ = water quench.
[D] Purchaser approval required.
[E] Match filler metal is available. Fabricators have also used AWS A5.14, Class ER, NiCrMo-3 and AWS A5.11, Class E, NiCrMo-3 filler metals.

SUPPLEMENTARY REQUIREMENT

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Macroetch Test

S1.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted according to Test Method E 340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Product Analysis

S2.1 A product analysis in accordance with Section 11 shall be made from one randomly selected forging representing each size and type (Note 1) of forging on the order. If the analysis fails to comply, each forging shall be checked or the lot rejected. All results shall be reported to the purchaser.

S3. Tension Test

S3.1 In addition to the requirements of Section 7, one tension specimen shall be obtained from a representative forging from each heat at a location agreed upon between the manufacturer and the purchaser. The results of the test shall comply with Table 3 and shall be reported to the purchaser.

S4. Magnetic Particle Examination

S4.1 All accessible surfaces of the finished forging shall be examined by a magnetic-particle method. The method shall be in accordance with Test Method A 275/A 275M. Acceptance limits shall be as agreed upon between the manufacturer and the purchaser.

S5. Liquid Penetrant Examination

S5.1 All accessible surfaces shall be examined by a liquid penetrant method in accordance with Practice E 165. Acceptance limits shall be as agreed upon between the manufacturer and the purchaser.

S6. Hydrostatic Testing

S6.1 A hydrostatic test at a pressure agreed upon between the manufacturer and the purchaser shall be applied by the manufacturer.

S7. Repair Welding

S7.1 No repair welding shall be permitted without prior approval of the purchaser. If permitted, the restrictions of Section 14 shall apply.

S8. Heat Treatment Details

S8.1 The manufacturer shall furnish a detailed test report containing the information required in 17.2 and shall include all pertinent details of the heat-treating cycle given the forgings.

S9. Material for Optimum Resistance to Stress-Corrosion Cracking

S9.1 Austenitic stainless steel shall be furnished in the solution-annealed condition as a final operation with no subsequent cold working permitted, except, unless specifically prohibited by the purchaser, straightening of bars from which parts are machined is permitted to meet the requirements of Specification A 484/A 484M.

S10. Corrosion Tests

S10.1 All austenitic stainless steel shall pass intergranular corrosion test performed in accordance with Practice E of Practices A 262.

S10.2 Intergranular corrosion test shall be performed on specimens of ferritic stainless steels as described in Practices A 763.

S10.3 For both the austenitic and ferritic stainless steels, details concerning the number of specimens and their source and location are to be a matter of agreement between the manufacturer and the purchaser.

S11. Special Filler Metal

S11.1 In repair welded F316, F316L, F316H, and F316N forgings, the deposited weld metal shall conform to E308 composition wire. Forgings repair welded with E308 weld metal shall be marked F _____W308.

S12. Hardness Test

S12.1 Each forging shall be hardness tested and shall meet the requirements of Table 3.

S13. Alternate Heat Treatment (Grade F 91)

S13.1 Grade F 91 shall be normalized in accordance with Section 5 and tempered at a temperature, to be specified by the purchaser, less than 1350°F [730°C]. It shall be the purchaser's responsibility to subsequently temper at 1350°F [730°C] minimum to conform to the requirements of the specification. All mechanical tests shall be made on material heat treated in accordance with Section 5. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S13" shall be included with the required marking of the forging.

S14. Heat Treatment of Austenitic Forgings

S14.1 The purchaser shall specify the heat treatment method (in 5.1 or in 5.3.1) that shall be employed.

S14.2 The manufacturer shall provide a test report containing the information required in 17.2 and shall include a statement of the heat treatment method employed.

S15. Grain Size for Austenitic Grades

S15.1 Forgings made from austenitic grades other than H grades shall be tested for average grain size by Test Method E 112. Details of the test shall be agreed upon between the manufacturer and the purchaser.

SPECIFICATION FOR SEAMLESS CARBON STEEL BOILER TUBES FOR HIGH-PRESSURE SERVICE

SA-192/SA-192M

(Identical with ASTM Specification A 192/A 192M-91) 98

1. Scope

1.1 This specification covers minimum-wall thickness, seamless carbon steel boiler and superheater tubes for high-pressure service.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ½ in. to 7 in. [12.7 to 177.8 mm] outside diameter and 0.085 to 1.000 in. [2.2 to 25.4 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in [3.2 mm] inside diameter or 0.015 in. [0.4 mm] thickness.

1.4 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520 shall supplement and supersede the requirements of this specification.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to described the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (seamless tubes),

4.1.3 Manufacture (hot-finished or cold-drawn),

4.1.4 Size (outside diameter and minimum wall thickness),

4.1.5 Length (specific or random),

4.1.6 Optional Requirements (Section 8),

4.1.7 Test report required (see section on Certification of Specification A 450/A 450M),

4.1.8 Specification designation, and

4.1.9 Special requirements.

5. Manufacture

5.1 Tubes shall be made by the seamless process and shall be either hot-finished or cold-finished, as specified.

6. Heat Treatment

98 **6.1** Hot-finished tubes need not be heat treated. Cold-finished tubes shall be heat treated after the final cold-finished at a temperature of 1200°F [650°C] or higher.

7. Chemical Composition

7.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, %	0.06–0.18
Manganese, %	0.27–0.63
Phosphorus, max	0.035
Sulfur, max, %	0.035
Silicon, max, %	0.25

7.2 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in 7.1 is not permitted.

8. Product Analysis

8.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube per 100 pieces for sizes over 3 in. [76.2 mm] and one tube per 250 pieces for sizes 3 in. [76.2 mm] and under; or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

8.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (see Note) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE — A lot consists of 250 tubes for sizes 3 in. [76.2 mm] and under and of 100 tubes for sizes over 3 in. [76.2 mm], prior to cutting to length.

9. Hardness Requirements

9.1 The tubes shall have a hardness number not exceeding the following:

Brinell Hardness Number (Tubes 0.200 in. [5.1 mm] and over in wall thickness)	Rockwell Hardness Number (Tubes less than 0.200 in. [5.1 mm] in wall thickness)
137 HB	77 HRB

10. Mechanical Tests Required

10.1 *Flattening Test* — One flattening test shall be made on specimens from each of two tubes selected from each lot (see Note) or fraction thereof.

10.2 *Flaring Test* — One flaring test shall be made on specimens from each end of two tubes selected from each lot (see Note) or fraction thereof. These tubes shall be selected apart from those used for the flattening test.

10.3 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot. The term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

10.4 *Hydrostatic Test* — Each tube shall be subjected to the hydrostatic pressure test, or instead of this test, a nondestructive test may be used when specified by the purchaser.

11. Forming Operations

11.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand

all forging, welding, and bending operations necessary for application without developing defects.

12. Product Marking

98 **12.1** In addition to the marking prescribed in Specification A 450/A 450M, the marking shall indicate whether the tube is hot finished or cold finished.

EXPLANATORY NOTE

NOTE — For purposes of design, the following tensile properties may be assumed:

Tensile strength, min, ksi [MPa]	47 [325]
Yield strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

SPECIFICATION FOR ALLOY-STEEL AND STAINLESS STEEL BOLTING MATERIALS FOR HIGH-TEMPERATURE SERVICE

SA-193/SA-193M

(Identical with ASTM Specification A 193/A 193M-95 except for differences in 3.1.1) 98

1. Scope

1.1 This specification covers alloy and stainless steel bolting material for pressure vessels, valves, flanges, and fittings for high-temperature service. The term "bolting material" as used in this specification covers bars, bolts, screws, studs, stud bolts and wire. Bars and wire shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be solution-annealed or annealed and strain-hardened.

1.2 Several grades are covered, including ferritic steels and austenitic stainless steels designated B5, B8, etc. Selection will depend upon design, service conditions, mechanical properties, and high-temperature characteristics.

NOTE 1 — The committee formulating this specification has included fifteen steel types that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent.

NOTE 2 — For grades of alloy-steel bolting material suitable for use at lower range of high-temperature applications, reference should be made to Specification A 354.

NOTE 3 — For grades of alloy-steel bolting material suitable for use in low-temperature applications, reference should be made to Specification A 320/A 320M.

1.3 Nuts for use with this bolting material are covered in Section 14.

1.4 Supplementary Requirements S1 through S8 are provided for use when additional tests or inspection are desired. These shall apply only when specified in the purchase order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 29/A 29M Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished

A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service

A 320/A 320M Specification for Alloy Steel Bolting Materials for Low-Temperature Service

A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 479/A 479M Specification for Stainless and Heat-Resisting Bars and Shapes for Use in Boilers and Other Pressure Vessels

A 484/484M Specification for General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 788 Specification for Steel Forgings, General Requirements
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E 21 Practice for Elevated Temperature Tension Tests of Metallic Materials
E 139 Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
E 150 Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times
E 151 Practice for Tension Tests of Metallic Materials at Elevated Temperatures with Rapid Heating and Conventional or Rapid Strain Rates.
E 292 Practice for Conducting Time-for-Rupture Notch Tension Tests of Materials
E 328 Methods for Stress-Relaxation Tests for Materials and Structures
E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms and Forgings
E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
E 709 Guide for Magnetic Particle Examination
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

2.2 *ANSI Standards:*
B1.1 Screw Threads
B18.2.1 Square and Hex Bolts and Screws
B18.3 Hexagon Socket and Spline Socket Screws

2.3 *AIAG Standard:*
AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

3. Ordering Information

3.1 The inquiry and order for material under this specification shall include the following as required to describe the material adequately:

3.1.1 Specification designation and grade.

3.1.2 Heat-treated condition (that is, normalized and tempered, or quenched and tempered, for the ferritic materials, and solution treated (Class 1), solution treated after finishing (Class 1A), and annealed-and-strain hardened (Class 2), for the austenitic stainless steels; Classes 1B and 1C apply to the solution-treated nitrogen-bearing stainless steels; Class ID applies to material solution treated by cooling rapidly from the rolling temperature),

3.1.3 Quantity (that is, number of pieces or weight),

3.1.4 Description of items required (that is, bars, bolts, screws, or studs),

3.1.5 Dimensions (that is, diameter, length of point, overall length, finish, shape, and threads),

3.1.6 Nuts, if required by purchaser, in accordance with 14.1,

3.1.7 Supplementary requirements, if any, and

3.1.8 Special requirements, in accordance with 6.3, 6.6, 13.3, 15.1, 16.1, 17.1, and 18.1.

4. Manufacture (Process)

4.1 The steel shall be produced by any of the following processes: open-hearth, basic-oxygen, electric-furnace or vacuum-induction melting (VIM). The primary melting method may incorporate separate degassing or refining. The molten steel may be vacuum-treated prior to or during pouring of the ingot or strand casting. The basic-oxygen process shall be limited to steels containing not over 6% chromium.

4.2 *Quality* — To ensure soundness, ferritic steel bars and wire shall be tested in accordance with Method E 381, or other suitable method as agreed upon between the purchaser and the producer. When bar or wire is supplied, the bar or wire producer shall perform the test. When fasteners are supplied, either the bar or wire producer or the fastener producer, as agreed upon between them, shall perform the test. Quality control procedures shall be sufficient to demonstrate that the testing was performed and that the results were acceptable. A bar lot consisting of one heat or 10 000 lbs whichever is smaller, shall be represented by a minimum of one macroetch. Visual examination of transverse sections shall show no imperfections worse than the macrographs of Method E 381 S4-R4-C4 or equivalent as agreed upon. District zones of solidification shall not be present.

5. Discard

5.1 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

6. Heat Treatment

6.1 Ferritic steels shall be properly heat treated as best suits the high-temperature characteristics of each grade. Immediately after rolling or forging, the bolting material shall be allowed to cool to a temperature below the cooling transformation range. The materials which are to be furnished in the liquid-quenched condition shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge") and quenched in a liquid medium under substantially uniform conditions for each quenching charge. Material Grade B16 shall be heated to a temperature range of 1700°F to 1750°F [925°C to 954°C] and oil quenched. The materials that are to be furnished in the normalized or air-quenched condition shall be reheated to the proper temperature to refine the grain and cooled uniformly in air to a temperature below the transformation temperature range. The material, whether liquid-quenched or normalized, shall then be uniformly reheated for tempering. The minimum tempering temperature shall be as specified in Table 2.

6.1.1 Quenched and tempered or normalized and tempered ferritic material that is subsequently cold drawn for dimensional control shall be stress-relieved after cold drawing. The minimum stress-relief temperature shall be 100°F [55°C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

6.2 Both B6 and B6X materials shall be held, at the tempering temperature for a minimum time of 1 h. Identification Symbol B6X material may be furnished in the as-rolled-and-tempered condition. Cold working is permitted with the hardness limitation (26 HRC maximum) of Table 2 for B6X grade.

6.3 Austenitic stainless steels shall receive a carbide solution treatment. After rolling, forging or heading, whether done hot or cold, the material shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide. Material thus treated is described as Class 1, Class 1B, or Class 1C. Alternatively, rolled or forged bar (except for grades 321 and 347) may be cooled rapidly immediately following hot working while the temperature is above 1750°F [955°C], so that grain boundary carbides are in solution, (see Specification A 479-88b and subsequent revisions). Material so treated is identified as Class 1D and shall be restricted to applications at temperatures less than 850°F [455°C]. If specified in the purchase order, material shall be solution treated in the finished condition; material so treated is described as Class 1A.

NOTE 4 — Heat treatment following operations performed on a limited portion of the product, such as heading, may result in non-uniform grain size and mechanical properties through the section affected.

6.4 If scale-free bright finish is required, this shall be specified in the purchase order.

6.5 When increased mechanical properties are desired, the austenitic bolting materials shall be solution annealed and strain hardened if specified in the purchase order; material so treated is identified as Class 2.

6.6 B7 and B7M bolting shall be heat treated by quenching in a liquid medium and tempering. For B7M bolting, the final heat treatment, which may be the tempering operation if conducted at 1150°F [620°C] minimum, shall be done after all machining and forming operations, including thread rolling, are complete.

6.6.1 Unless otherwise specified, material for Grade B7 may be heat treated by Furnace, the Induction or the Electrical Resistance method.

NOTE 5 — It should be taken into consideration that stress-relaxation properties may vary from heat lot to heat lot or these properties may vary from one heat treating method to another. The purchaser may specify Requirement S8, if stress-relaxation testing is desired.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1. Steels with added lead shall not be used.

7.2 The steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element. Furthermore, elements present in concentrations greater than 0.75 weight/% shall be reported. Chemical analysis shall be performed in accordance with Test Methods A 751.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 7. This analysis shall be made from a test specimen taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7. For strand cast materials, the

requirements of 8.2 and 8.3 of Specification A 788 shall be met. Should the purchaser deem it necessary to have the transition zone of two heats sequentially cast discarded, the purchaser shall invoke Supplementary Requirement S3 of Specification A 788.

9. Product Analysis

9.1 An analysis may be made by the purchaser from samples representing the bolting material. The chemical composition thus determined shall conform to the requirements of Section 7.

10. Mechanical Properties

10.1 *Tensile Properties;*

10.1.1 *Requirements* — The material as represented by the tension specimens shall conform to the requirements prescribed in Table 2 at room temperature after heat treatment.

10.1.2 *Method of Test* — Tension test shall be made in accordance with Test Methods and Definitions A 370, including the parts of Annex A3 "Steel Fasteners" applicable to machined test specimens. The speed of testing shall not exceed the limits specified in 11.4.1 of Test Methods and Definitions A 370. The yield strength corresponding to a limiting permanent offset of 0.2% of the gage length of the specimen shall be determined.

10.2 *Hardness Requirements:*

10.2.1 The hardness shall conform to the requirements prescribed in Table 2. Hardness testing shall be performed in accordance with either Test Methods and Definitions A 370 or with Test Methods F 606. Except for Grade B7M, final acceptance is base on tensile strength when there is a conflict between tensile and hardness results.

10.2.2 *Grade B7M* — The maximum hardness of the grade shall be 235 HB or 99 HRB (conversion in accordance with Table 2B of Test Methods and Definitions A 370). The minimum hardness shall not be less than 200 HB or 93 HRB. Conformance to this hardness shall be insured by testing the hardness of each stud or bolt by Brinell or Rockwell B methods in accordance with 10.2.1. The use of 100% electromagnetic testing for hardness as an alternative to 100% indentation hardness testing is permissible when qualified by sampling using indentation hardness testing. Each lot tested for hardness electromagnetically shall be 100% examined in accordance with Practice E 566. Following electromagnetic testing for hardness a random sample of a minimum or 100 pieces of each heat of steel in each purchase lot (as defined in 11.1.3) shall be tested by indentation hardness methods. All samples must meet hardness requirements to permit acceptance of the lot. If any one sample is outside of the specified maximum or minimum hardness, the lot shall be rejected and either reprocessed and resampled or tested 100% by indentation hardness methods. In the event a controversy exists relative to minimum strength, tension tests shall prevail over hardness readings. Product which has been 100% tested and found acceptable shall have a line under the grade symbol.

10.2.2.1 Surface preparation for indentation hardness testing shall be in accordance with Test Methods E 18. Hardness tests shall be performed on the end of the bolt or stud. When this is impractical, the hardness test shall be performed elsewhere.

11. Test Specimens

11.1 Tension test specimens taken from finished bolts, screws, studs, or stud bolts shall be machined to the form and dimensions and shall be taken from position shown in A3.2.1.7 of Test Methods and Definitions A 370. Tension Test specimens from bar stock are covered by Annex A1.3 of Test Methods and Definitions A 370, Annex A1.

11.1.2 *Number of Tests* — For heat-treated bars, one tension test shall be made for each diameter of each heat represented in each tempering charge. When heat treated without interruption in continuous furnaces, the material in a lot shall be the same heat, same prior condition, same size and subjected to the same heat treatment. Not fewer than two tension tests are required for each lot containing 20 000 lb [9000 kg] or less. Every additional 10 000 lb [4500 kg] or fraction thereof requires one additional test.

11.1.3 For studs, bolts, screws, etc., one tension test shall be made for each diameter of each heat involved in the lot. Each lot shall consist of the following:

Diameter, in. [mm]	Lot Size
1⅛ [30] and under	1500 lb [780 kg] or fraction thereof
Over 1⅛ [30] to 1¾ [45], incl	4500 lb [2000 kg] or fraction thereof
Over 1¾ [45] to 2½ [65], incl	6000 lb [2700 kg] or fraction thereof
Over 2½ [65]	100 pieces or fraction thereof

11.1.4 Tension tests are not required to be made on bolts, screws, studs, or stud bolts that are fabricated from heat-treated bars furnished in accordance with the requirements of this specification and tested in accordance with 11.1.2, provided they are not given a subsequent heat treatment.

12. Retests

12.1 If the results of the mechancal tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension tests shall be made from such lot, all of which shall conform to the requirements specified.

13. Workmanship, Finish, and Appearance

13.1 Bolts, screws, studs, and stud bolts shall be pointed and shall have a workmanlike finish. Points shall be flat and chamfered or rounded at option of the manufacturer. Length of points on studs and stud bolts shall be not less than one nor more than two complete threads as measured from the extreme end parallel to the axis. Length of studs and stud bolts shall be measured from first thread to first thread.

13.2 Standard permissible variations for dimensions of bars shall be as prescribed in Table 3. Aside from the tolerance given in Table 3, additional tolerances for the basic materials are given in Specification A 29/A 29M and Specification A 484/A484M, latest revisions.

13.3 Bolt heads shall be in accordance with the dimensions of ANSI B18.2.1. Unless otherwise specified in the purchase order, the Heavy Hex Screws Series should be used, except the maximum body diameter and radius of fillet may be the same as for the Heavy Hex Bolt Series. The body diameter and head filet radius for sizes of Heavy Hex Cap Screws and Bolts that are not shown in their respective tables in ANSI B18.2.1 may be that shown in the corresponding Hex Cap Screw and Bolt Tables respectively. Socket head fasteners shall be in accordance with ANSI B18.3.

14. Nuts

14.1 Bolts, studs, and stud bolts shall be furnished with nuts, when specified in the purchase order. Nuts shall conform to Specification A 194/A 194M.

15. Threads

15.1 All bolts, studs, stud bolts, and accompanying nuts, unless otherwise specified in the purchase order shall be threaded in accordance with ANSI B1.1 Class 2A fit, sizes 1 in. [25 mm] and smaller in diameter with the coarse-thread series, and $1\frac{1}{8}$ in. [28 mm] and larger in diameter with the 8-pitch-thread series.

15.2 Where practical, all threads shall be formed after heat treatment. Class 1A, Grades B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA, AND B8MLCuNA, and Class 1C Grades B8RA and B8SA are to be solution treated in the finished condition.

16. Inspection

16.1 The inspector representing the purchaser shall have entry, at all time while work on the contract of the purchaser is being performed, to all parts of the place of manufacture that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified in the purchase order and shall be so conducted as not to interfere unnecessarily with the operation of the works.

16.2 *Certification by Manufacturer* — When agreed upon in writing between the manufacturer and the purchaser, a certification that the material conforms to the requirements of the specification shall be the basis of acceptance of the material. Otherwise, the manufacturer shall report to the purchaser or his representative the result of the chemical analysis macroetch inspection, and mechanical tests made in accordance with the specification. The certification shall state the method of heat treatment employed. Certification shall include the specification year date of issue. If furnace treated, induction treated, or electrical resistance treated material is specified, (see 6.6), the certification shall state the method of heat treatment employed.

17. Rejection and Rehearing

17.1 Unless otherwise specified in the basis of purchase, any rejection based on tests made in accordance with Section 9 shall be reported to the manufacturer within 30 days from the receipt of samples by the purchaser.

98 **17.2** Material that shows defects subsequent to its acceptance at the place of manufacture shall be rejected, and the manufacture shall be notified.

17.3 Samples tested in accordance with Section 9 that represent rejected material shall be preserved for 2 weeks from the date of the test report. In the case of dissatisfaction with the results of the test, the manufacturer may make claim for a rehearing within that time.

18. Product Marking

18.1 Grade and manufacturer's identification symbols shall be applied to one end of studs $\frac{3}{8}$ in. [10 mm] in diameter and larger and to the heads of bolts $\frac{1}{4}$ in. [6 mm] in diameter and larger. (If the available area is inadequate, the grade symbol may be marked on one end and the the manufacturer's identification symbol marked on the other end.) The identification symbol shall be as shown in Table 4 and 5. Grade B7M which has been 100% evaluated in conformance with the specification, shall have a line under the grade symbol to distinguish it from B7M produced to previous specification revisions not requiring 100% hardness testing.

18.2 For bolting materials, including threaded bars, that are furnished bundled and tagged or boxed, the tags and boxes shall carry the grade symbol for the material identification and the manufacturer's identification mark or name.

18.3 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

18.4 *Bar Coding* — In addition to the requirements in 18.1, 18.2, and 18.3, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard B-5 02.00. If used on small items, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 hardness; heat treatment

TABLE 1
CHEMICAL REQUIREMENTS (COMPOSITION, PERCENT) [NOTE (1)]

Type	Ferritic Steels			
Identification Symbol	B5		B6 and B6X	
Grade	5% Chromium (AISI Type 501)		12% Chromium (AISI Type 410)	
			AISI Type 410	
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]
Carbon	0.10 min	0.01 under	0.15 max	0.01 over
Manganese, max	1.00	0.03 over	1.00	0.03 over
Phosphorus, max	0.040	0.005 over	0.040	0.005 over
Sulfur, max	0.030	0.005 over	0.03	0.005 over
Silicon	1.00 max	0.05 over	1.00 max	0.05 over
Chromium	4.0–6.0	0.10	11.5–13.5	0.15
Molybdenum	0.40–0.65	0.05	. . .	. . .

Type	Ferritic Steels			
Identification Symbol	B7, B7M		B16	
Grade	Chromium-Molybdenum (AISI 4140, 4142, 4145, 4140H, 4142H, and 4145H)		Chromium-Molybdenum-Vanadium	
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]
Carbon	0.37–0.49 [Note (3)]	0.02	0.36–0.47	0.02
Manganese	0.65–1.10	0.04	0.45–0.70	0.03
Phosphorus, max	0.035	0.005 over	0.035	0.005 over
Sulfur, max	0.040	0.005 over	0.040	0.005 over
Silicon	0.15–0.35	0.02	0.15–0.35	0.02
Chromium	0.75–1.20	0.05	0.80–1.15	0.05
Molybdenum	0.15–0.25	0.02	0.50–0.65	0.03
Vanadium	. . .	. . .	0.25–0.35	0.03

Type	Austenitic Steels, [Note (4)] Classes 1, 1A, 1D, and 2							
Identification Symbol	B8, B8A		B8C, B8CA		B8M, B8MA B8M2, B8M3		B8P, B8PA	
Grade	Unstabilized 18 Chromium-8 Nickel (AISI Type 304)		Stabilized 18 Chromium-8 Nickel (AISI Type 347)		18 Chromium-10 Nickel-2 Molybdenum (AISI Type 316)		Unstabilized 18 Chromium-8 Nickel (AISI Type 305 with restricted carbon)	
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.08	0.01 over	0.08	0.01 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	17.0–19.0	0.20	16.0–18.0	0.20	17.0–19.0	0.20
Nickel	8.0–10.5	0.15	9.0–13.0	0.15	10.0–14.0	0.15	10.5–13.0	0.15
Molybdenum	. . .	. . .	. . .	. . .	2.00–3.00	0.10	. . .	. . .
Columbium + tantalum	. . .	. . .	10 × carbon content, min	0.05 under	. . .	. . .	. . .	. . .

TABLE 1 (CONT'D)
CHEMICAL REQUIREMENTS (COMPOSITION, PERCENT) [NOTE (1)]

Type	Austenitic Steels, [Note (4)] Classes 1A, 1B, 1D, and 2				
Identification Symbol	B8N, B8NA		B8MN, B8MNA		B8MLCuN, B8MLCuNA
Grade	(AISI Type 304N)		(AISI Type 316N)		Unstabilized, 20 Chromium, 18 Nickel, 6 Molybdenum with restricted carbon
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]	Range
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.020
Manganese, max	2.00	0.04 over	2.00	0.04 over	1.00
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.030
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.010
Silicon, max	1.00	0.05 over	1.00	0.05 over	0.80
Chromium	18.0–20.0	0.20	16.0–18.0	0.20	19.5–20.5
Nickel	8.0–10.5	0.15	10.0–14.0	0.15	17.5–18.5
Molybdenum	. . .	. . .	2.00–3.00	0.10	6.0–6.5
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01	0.18–0.22
Copper	. . .	. . .	. . .	. . .	0.50–1.00

Type	Austenitic Steels [Note (4)], Classes 1, 1A, and 2	
Identification Symbol	B8T, B8TA	
Grade	Stabilized 18 Chromium-8 Nickel (AISI Type 321)	
	Range	Product Variation, Over or Under [Note (2)]
Carbon, max	0.08	0.01 over
Manganese, max	2.00	0.04 over
Phosphorus, max	0.045	0.010 over
Sulfur, max	0.030	0.005 over
Silicon, max	1.00	0.05 over
Nickel	9.0–12.0	0.15
Chromium	17.0–19.0	0.20
Titanium	5 × carbon content, min	0.05 under

Type	Austenitic Steels [Note (4)], Classes 1C and 1C			
Identification Symbol	B8R, B8RA		B8S, B8SA	
Grade	22 Chromium-13 Nickel-5 Manganese		18 Chromium-8 Nickel-4 Silicon + Nitrogen	
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]
Carbon, max	0.06	0.01 over	0.10	0.01 over
Manganese	4.0–6.0	0.05	7.0–9.0	0.06
Phosphorus, max	0.040	0.005 over	0.040	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00 max	0.05 over	3.5–4.5	0.15
Chromium	20.5–23.5	0.25	16.0–18.0	0.20
Nickel	11.5–13.5	0.15	8.0–9.0	0.10
Molybdenum	1.50–3.00	0.10	. . .	. . .
Nitrogen	0.20–0.40	0.02	0.08–0.18	0.01
Columbium + tantalum	0.10–0.30	0.05	. . .	. . .
Vanadium	0.10–0.30	0.02	. . .	. . .

TABLE 1 (CONT'D)
CHEMICAL REQUIREMENTS (COMPOSITION, PERCENT) [NOTE (1)]

Type	Austenitic Steels [Note (4)], Classes 1, 1A and 1D			
Identification Symbol	B8LN, B8LNA		B8MLN, B8MLNA	
Grade	(AISI Type 304N with restricted carbon)		(AISI Type 316N with restricted carbon)	
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]
Carbon, max	0.030	0.005 over	0.030	0.005 over
Manganese	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	16.0–18.0	0.20
Nickel	8.0–10.5	0.15	10.0–14.0	0.15
Molybdenum	. . .	. . .	2.00–3.00	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01

NOTES:
(1) The intentional addition of Bi, Se, Te, and Pb is not permitted.
(2) Product analysis — Individual determinations sometimes vary from the specified limits on ranges as shown in the tables. The several determinations of any individual element in a heat may not vary both above and below the specified range.
(3) For bar sizes over 3½ in. [90 mm], inclusive, the carbon content may be 0.50%, max. For the B7M grade, a minimum carbon content of 0.28% is permitted, provided that the required tensile properties are met in the section sizes involved; the use of AISI 4130 or 4130H is allowed.
(4) Classes 1 and 1D are solution treated. Classes 1, 1B and some 1C (B8R and B8S) products are made from solution treated material. Class 1A (B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA and B8MNA) and some Class 1C (B8RA and B8SA) products are solution treated in the finished condition. Class 2 products are solution treated and strain hardened.

TABLE 2
MECHANICAL REQUIREMENTS

Grade	Diameter, in. [mm]	Minimum Tempering Temperature, °F [°C]	Tensile Strength, min, ksi [MPa]	Yield Strength, min, 0.2% offset, ksi [MPa]	Elongation in 4 D, min, %	Reduction of Area, min, %	Hardness, max
		Ferritic Steels					
B5							
4 to 6% chromium	up to 4 [100], incl	1100 [593]	100 [690]	80 [550]	16	50	. . .
B6	up to 4 [100], incl	1100 [593]	110 [760]	85 [585]	15	50	. . .
13% chromium							
B6X	up to 4 [100], incl	1100 [593]	90 [620]	70 [485]	16	50	26 HRC
13% chromium							
B7							
Chromium-molybdenum	2½ [65] and under	1100 [593]	125 [860]	105 [720]	16	50	321 HB or 35 HRC
	over 2½ to 4, incl [65 to 100]	1100 [593]	115 [795]	95 [655]	16	50	302 HB or 33 HRC
B7M [Note (1)]	over 4 to 7, incl [100 to 180]	1100 [593]	100 [690]	75 [515]	18	50	277 HB or 29 HRC
Chromium-molybdenum		1150 [620]	100 [690]	80 [550]	18	50	235 HB or 99 HRB
	4 [101.6] and under	1150 [620]	100 [690]	80 [550]	18	50	235 BHN or 99 R/B
	over 4 to 7 [101.6 to 117.8]	1150 [620]	100 [690]	75 [515]	18	50	235 BHN or 99 R/B
B16							
Chromium-molybdenum-vanadium	2½ [65] and under	1200 [650]	125 [860]	105 [725]	18	50	321 HB or 35 HRC
	over 2½ to 4 [65 to 100], incl	1200 [650]	110 [760]	95 [655]	17	45	302 HB or 33 HRC
	over 4 to 7 [100 to 180], incl	1200 [650]	100 [690]	85 [585]	16	45	277 HB or 29 HRC

TABLE 2
MECHANICAL REQUIREMENTS (CONT'D)

Class and Grade, Diameter, in. [mm]	Heat Treatment [Note (2)]	Tensile Strength, min, ksi [MPa]	Yield Strength, min, 0.2 % offset, ksi [MPa]	Elongation in 4 D, min, %	Reduction of Area, min %	Hardness, max
Austenitic Steels						
Classes 1 and 1D: B8, B8C, B8M, B8P, B8T, B8LN, B8MLN, all diameters	carbide solution treated	75 [515]	30 [205]	30	50	223 HB or 96 HRB [Note (3)]
Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA, B8MLCuNA, all diameters	carbide solution treated in the finished condition	75 [515]	30 [205]	30	50	192 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, and B8MLCuN, all diameters	carbide solution treated	80 [550]	35 [240]	30	40	223 HB or 96 HRB [Note (3)]
Classes 1C and 1D: B8R, all diameters	carbide solution treated	100 [690]	55 [380]	35	55	271 HB or 28 HRC
B8RA, all diameters	carbide solution treated in the finished condition	100 [690]	55 [380]	35	55	271 HB or 28 HRC
B8S, all diameters	carbide solution treated	95 [655]	50 [345]	35	55	271 HB or 28 HRC
B8SA, all diameters	carbide solution treated in the finished condition	95 [655]	50 [345]	35	55	271 HB or 28 HRC
Class 2: B8, B8C, B8P, B8T, B8N, and B8MLCuN, 3/4 [20] and under	carbide solution treated and strain hardened	125 [860]	100 [690]	12	35	321 HB or 35 HRC
over 3/4 to 1, [20 to 25] incl		115 [795]	80 [550]	15	35	321 HB or 35 HRC
over 1 to 1 1/4 [25.4 to 31.6] incl		105 [725]	65 [450]	20	35	321 HB or 35 HRC
over 1 1/4 to 1 1/2 [32 to 40] incl		100 [690]	50 [345]	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN [Note (4)]	carbide solution treated and strain hardened	110 [760]	95 [665]	15	45	321 HB or 35 HRC
3/4 [19.05] and under						
over 3/4 to 1 [19.05 to 25.4] incl		100 [690]	80 [550]	20	45	321 HB or 35 HRC
over 1 to 1 1/4 [25.4 to 31.6] incl		95 [655]	65 [450]	25	45	321 HB or 35 HRC
over 1 1/4 to 1 1/2 [31.6 to 37.9] incl		90 [620]	50 [345]	30	45	321 HB or 35 HRC
Class 2B: B8M2 [Note (4)]	carbide solution treated and strain hardened	95 [655]	75 [515]	25	40	321 HB or 35 HRC
2 [50.8] and under						
over 2 to 2 1/2 [50.8 to 63.2] incl		90 [620]	65 [450]	30	40	321 HB or 35 HRC
over 2 1/2 to 3 [63.2 to 76.2] incl		80 [550]	55 [380]	30	40	321 HB or 35 HRC
Class 2C: B8M3 [Note (4)]	carbide solution treated and strain hardened	85 [585]	65 [450]	30	60	321 HB or 35 HRC
2 [50.8] and under						
over 2 [50.8]		85 [585]	60 [415]	30	60	321 HB or 35 HRC

NOTES:
(1) To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).
(2) Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over 3/4 in. [20 mm] in diameter.
(3) For sizes 3/4 in. [20 mm] in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.
(4) For diameters 1 1/2 [38] and over, center (core) properties may be lower than indicated by test reports which are based on values determined at 1/2 radius.

TABLE 3
PERMISSIBLE VARIATIONS IN SIZE OF HOT-ROLLED BARS

Specified Size, in. [mm]	Permissible Variations from Specified Size					
	Over		Under		Out-of-Round	
	in.	mm	in.	mm	in.	mm
5/16 [8] and under	0.005	0.13	0.005	0.13	0.008	0.20
Over 5/16 to 7/16 [11], incl	0.006	0.15	0.006	0.15	0.009	0.23
Over 7/16 to 5/8 [16], incl	0.007	0.18	0.007	0.18	0.010	0.25
Over 5/8 to 7/8 [22], incl	0.008	0.20	0.008	0.20	0.012	0.30
Over 7/8 to 1 [25], incl	0.009	0.23	0.009	0.23	0.013	0.33
Over 1 to 1 1/8 [29], incl	0.010	0.25	0.010	0.25	0.015	0.38
Over 1 1/8 to 1 1/4 [32], incl	0.011	0.28	0.011	0.28	0.016	0.41
Over 1 1/4 to 1 3/8 [35], incl	0.012	0.30	0.012	0.30	0.018	0.46
Over 1 3/8 to 1 1/2 [38], incl	0.014	0.36	0.014	0.36	0.021	0.53
Over 1 1/2 to 2 [50], incl	1/64	0.40	1/64	0.40	0.023	0.58
Over 2 to 2 1/2 [65], incl	1/32	0.79	0	0	0.023	0.58
Over 2 1/2 to 3 1/2 [90], incl	3/64	1.19	0	0	0.035	0.89
Over 3 1/2 to 4 1/2 [115], incl	1/16	1.59	0	0	0.046	1.17
Over 4 1/2 to 5 1/2 [140], incl	5/64	1.98	0	0	0.058	1.47
Over 5 1/2 to 6 1/2 [165], incl	1/8	3.18	0	0	0.070	1.78
Over 6 1/2 to 7 [180], incl	5/32	3.97	0	0	0.085	2.16

TABLE 4
MARKING OF FERRITIC STEELS

Grade	Marking
B5	B5
B6	B6
B6X	B6X
B7	B7
B7M [Note (1)]	B7M
	B7M
B16	B16

NOTE:
(1) For explanations, see 10.2.2 and 18.1.

TABLE 5
MARKING OF AUSTENITIC STEELS [NOTE (1)]

Class	Grade	Marking
Class 1	B8	B8
	B8C	B8C
	B8M	B8M
	B8P	B8P
	B8T	B8T
	B8LN	B8F
	B8MLN	B8G
Class 1A	B8A	B8A
	B8CA	B8B
	B8MA	B8D
	B8PA	B8H
	B8TA	B8J
	B8LNA	B8L
	B8MLNA	B8K
	B8NA	B8V
	B8MNA	B8W
	B8MLCuNA	B9K
Class 1B	B8N	B8N
	B8MN	B8Y
	B8MLCuN	B9J
Class 1C	B8R	B9A
	B8RA	B9B
	B8S	B9D
	B8SA	B9F
Class 1D	B8	B94
	B8M	B95
	B8P	B96
	B8LN	B97
	B8MLN	B98
	B8N	B99
	B8MN	B100
	B8R	B101
	B8S	B102
Class 2	B8	B8
	B8C	B8C
	B8P	B8P
	B8T	B8T
	B8N	B8N
	B8M	B8M
	B8MN	B8Y
	B8MLCuN	B9J
Class 2B	B8M2	B9G
Class 2C	B8M3	B9H

NOTE:
(1) Classes 1, 1A, 1B, 1C, 2, 2B, and 2C may be marked with either grade or marking listed. Class 1D may only be marked with marking listed.

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order and in the Ordering Information, in which event the specified tests shall be made before shipment of the product.

S1. High-Temperature Tests

S1.1 Tests to determine high temperature properties shall be made in accordance with Practice E 21, and Practices E 139, E 292, E 150, and E 151.

S2. Charpy Impact Tests

S2.1 Charpy impact tests based on the requirements of Specification A 320/A 320M, Section 6 and 7 shall be made as agreed between the manufacturer and the purchaser. When testing temperatures are as low as those specified in Specification A 320/A 320M, bolting should be ordered to that specification in preference to this specification.

S3. 100% Hardness Testing of Grade B7M

S3.1 Each Grade B7M bolt or stud shall be tested for hardness by indentation method and shall meet the requirements specified in Table 2.

S4. Hardness Testing of Grade B16

S4.1 For bolts or studs $2\frac{1}{2}$ in. [65 mm] or smaller, the hardness for Grade B16 shall be measured on or near the end of each bolt or stud using one of the methods prescribed in 10.2.1 for the Brinell or Rockwell C test. The hardness shall be in the range 253-319 HB or 25-34 HRC.

S5. Product Marking

98 **S5.1** Grade and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts smaller than $\frac{1}{4}$ in. [6 mm] in diameter and studs smaller than $\frac{3}{8}$ in. [10 mm] in diameter and for $\frac{1}{4}$ in. [6 mm] in diameter studs requiring more than a total of three symbols, the marking shall be a matter of agreement between the purchaser and the manufacturer.

S6. Stress Relieving

S6.1 A stress-relieving operation shall follow straightening after heat treatment.

S6.2 The minimum stress-relieving temperature shall be 100°F [55°C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

S7. Magnetic Particle Inspection

S7.1 Bars shall be magnetic particle examined in accordance with Guide E 709. Bars with indications of cracks or seams are subject to rejection if the indications extend more than 3% of the diameter into the bar. 98

S8. Stress-Relaxation Testing

S8.1 Stress-Relaxation Testing, when required, shall be done in accordance with Practice E 328. The test shall be performed at 850°F [454°C] for a period of 100 h. The initial stress shall be 50 M psi (345 MPa). The residual stress at 100 h shall be 17 M psi (117 MPa) minimum.

APPENDIX

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steel by reducing oversized bars or wire to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar, so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening.

X1.2 Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined. The minimum bar size that can be used, however, is established by the configuration of the fastener, so that the configuration can affect the strength of the fastener.

X1.3 For example, a stud of a particular alloy and size may be machined from a smaller diameter bar than a bolt of the same alloy and size because a larger diameter bar is required to accommodate the head of the bolt. The stud, therefore, is likely to be stronger than the same size bolt in a given alloy.

X2. COMPARISON OF GRADE DESIGNATION MARKING USED FOR AUSTENITIC STEEL IN VARIOUS EDITIONS OF A 193/A 193M

TABLE X2.1
MARKING SYMBOL CROSS REFERENCE

Class	Grade Designation	Marking Symbol Used Prior to A 193/A 193M–89	Marking Symbol Used in A 193/A 193M–89 through A 193/A 193M–91a	Marking Symbol Used in A 193/A 193M–92 and Later Versions
1	B8	B8	B8	B8
1	B8C	B8C	B8C	B8C
1	B8M	B8M	B8M	B8M
1	B8P	B8P	B8P	B8P
1	B8T	B8T	B8T	B8T
1	B8LN	B8LN	B80 or B8LN[B]	B8F or B8LN
1	B8MLN	B8MLN	B81 or B8MLN[B]	B8G or B8MLN
1A	B8A	B8A	B8A	B8A
1A	B8CA	B8CA	B82 or B8CA[B]	B8B or B8CA
1A	B8MA	B8MA	B83 or B8MA[B]	B8D or B8MA
1A	B8PA	B8PA	B84 or B8PA[B]	B8H or B8PA
1A	B8TA	B8TA	B85 or B8TA[B]	B8J or B8TA
1A	B8LNA	B8LNA	B86 or B8LNA[B]	B8L or B8LNA
1A	B8MLNA	B8MLNA	B87 or B8MLNA[B]	B8K or B8MLNA
1A	B8NA	B8NA	B88 or B8NA[B]	B8V or B8NA
1A	B8MNA	B8MNA	B89 or B8MNA[B]	B8W or B8MNA
1A	B8MLCuNA			B9K[C] or B8MLCuNA
1B	B8N	B8N	B8N	B8N
1B	B8MN	B8MN	B90 or B8MN[B]	B8Y or B8MN
1B	B8MLCuNA		B103[A] or B8MLCuNA[B]	[C]
1B	B8MLCuN			B9J[C] or B8MLCuN
1C	B8R	B8R	B8R	B9A or B8R
1C	B8RA	B8RA	B91 or B8RA[B]	B9B or B8RA
1C	B8S	B8S	B8S	B9D or B8S
1C	B8SA	B8SA	B92 or B8SA[B]	B9F or B8SA
1D	B8		B94[A]	B94
1D	B8M		B95[A]	B95
1D	B8P		B96[A]	B96
1D	B8LN		B97[A]	B97
1D	B8MLN		B98[A]	B98
1D	B8N		B99[A]	B99
1D	B8MN		B100[A]	B100
1D	B8R		B101[A]	B101
1D	B8S		B102[A]	B102
2	B8	B8	B8	B8
2	B8C	B8C	B8C	B8C
2	B8P	B8P	B8P	B8P
2	B8T	B8T	B8T	B8T
2	B8N	B8N	B8N	B8N
2	B8M	B8M	B8M	B8M
2	B8MN	B8MN	B93 or B8MN[B]	B8Y or B8MN
2	B8MLCuN		B104[A] or B8MLCuN[B]	B9J[C] or B8MLCuN
2B	B8M2	B8M2	B8M2	B9G or B8M2
2C	B8M3	B8M3	B8M3	B9H or B8M3

[A] Class or Grade added when A 193/A 193M–91A was published.
[B] Option to mark with grade symbol added when A 193/A 193M–91a was published.
[C] Class designation corrected when A 193/A 193M–93a was published.

SPECIFICATION FOR CARBON AND ALLOY STEEL NUTS FOR BOLTS FOR HIGH-PRESSURE AND HIGH-TEMPERATURE SERVICE

SA-194/SA-194M

(Identical with ASTM Specification A 194/A 194M-95a except for editorial differences in 4.1.1 and S5.1.) 98

1. Scope

1.1 This specification covers a variety of carbon, alloy, and martensitic stainless steel nuts in the size range ¼ through 4 in. [6.4 through 101.6 mm] nominal. It also covers austenitic stainless steel nuts in the size range ¼ in. [6.4 mm] nominal and above. These nuts are intended for high-pressure or high-temperature service or both. Grade substitutions without the purchaser's permission are not allowed.

1.2 Bars from which the nuts are made shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be solution annealed or annealed and strain-hardened. When annealed and strain hardened austenitic stainless steel is ordered in accordance with Supplementary Requirements S1, the purchaser should take special care to ensure that 7.2.2, Supplementary Requirements S1, and Appendix X1 are thoroughly understood.

1.3 Supplementary requirements (S1 through S6) of an optional nature are provided. These shall apply only when specified in the inquiry, contract, and order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in noncomformance with the specification.

NOTE — Grade 2M has been replaced with Grade 2HM. During a transition period both grade markings are acceptable.

2. Referenced Documents

2.1 *ASTM Standards:*

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for

A 276 Specification for Stainless and Heat-Resisting Steel Bars and Shapes

A 320/A 320M Specification for Alloy-Steel Bolting Materials for Low-Temperature Service

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 484/A 484M Specification for General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 788 Specification for Steel Forgings, General Requirements

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

2.2 *American National Standards:*
B1.1 Unified Screw Threads
B1.2 Gages and Gaging for Unified Screw Threads
B18.2.2 Square and Hex Nuts

2.3 *AIAG Standard:*
AIAG B-5 02.00 Primary Metal Identification Tag Application Standard

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *Lot:*

3.1.1.1 Unless otherwise specified (see 3.1.1.2), a lot is the quantity of nuts of a single nominal size and grade produced by the same manufacturing process.

3.1.1.2 When Supplementary Requirement S6 is invoked on the purchase order, the following definitions of a lot shall apply:

For Grade 8 Nuts — The quantity of all the nuts of a single nominal diameter and grade made from the same heat of steel and made by the same manufacturing process.

For All Other Grade Nuts (see 7.2 and 7.1.2.1) — All the nuts of a single nominal diameter and grade made from the same heat number and heat treated in the same batch if batch-type heat treating equipment is used or heat treated in the same continuous run of not more than 8 h under the same conditions if continuous-type heat treating equipment is used.

3.1.2 *Type:*

3.1.2.1 *For Grade 8 Nuts* — Variations within the grade designated by a letter and differentiated by chemistry and by manufacturing process.

3.1.2.2 *For Grade 6 Nuts* — Variations within the grade designated by the letter F as differentiated by chemical additions made for machineability.

3.1.3 *Series* — The dimensional relationship and geometry of the nuts as described in ANSI B18.2.2.

4. Ordering Information

4.1 The inquiry and order for material under this specification shall include the following as required to describe the material adequately:

4.1.1 Specification designation and grade,

4.1.2 Quantity, number of pieces,

4.1.3 Dimensions (see Section 9),

4.1.4 Options in accordance with 6.1, 7.2.2.1, 9.1, 9.2, 10.3, 11, 12, and 13, and

4.1.5 Supplementary Requirements, if any.

5. Manufacture (Process)

5.1 The steel shall be produced by any one of the following processes: open-hearth, basic-oxygen, electric-furnace, or vacuum-induction melting (VIM). The primary melting method may incorporate separate degassing or refining. The molten steel may be vacuum-treated prior to or during pouring of the ingot or strand casting. The basic-oxygen process shall be limited to steels containing not over 6% chromium.

5.1.1 *Quality* — To ensure soundness, ferritic steel bars shall be tested in accordance with Method E 381, or other suitable method as agreed upon between the purchaser and the producer. Either the bar producer or the nut producer, as agreed upon between them, shall perform the test. Quality control procedures shall be sufficient to demonstrate that the testing was performed and that the results were acceptable. A bar lot consisting of one heat or 10 000 lbs, whichever is smaller, shall be represented by a minimum of one macroetch. Visual examination of transverse sections shall show no imperfections worse than the macrographs of Method E 381 S4-R4-C4 or equivalent as agreed upon. Distinct zones of solidification shall not be present.

5.2 Stainless steels for all types of Grade 6 and 8 nuts shall be made by one of the following processes:

5.2.1 Electric-furnace (with separate degassing and refining optional),

5.2.2 Vacuum induction furnace, or

5.2.3 Either of the above followed by electroslag remelting, or consumable-arc remelting.

5.3 The steel producer shall exercise adequate control to eliminate excessive unhomogeneity, nonmetallics, pipe, porosity, and other defects.

5.4 Grades 1 and 2 nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled, or cold-drawn bars.

5.4.1 All Grade 1 and 2 nuts made by cold forging or by machining from cold-drawn bars shall be stress-relief annealed at a temperature of at least 1000°F [538° C].

5.4.2 Grade 1 and 2 nuts made by hot forging or by machining from hot-forged or hot-rolled bars need not be given any stress relief annealing treatment.

5.5 Grades 2HM, 2H, 3, 4, 6, 6F, 7, 7M, and 16 nuts shall be hot or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and shall be heat treated to meet the required mechanical properties. However, nuts machined from heat-treated bars need not be reheat treated. See Supplementary Requirement S4 for nuts to be used in low-temperature applications (Specification A 320/A 320M). These grades of nuts shall be reheated above the critical range of the steel, quenched in a suitable medium, and then tempered at a temperature not less than the following:

Grade and Type	Minimum Tempering Temperature, °F [°C]
2H	850 [455]
2HM	1150 [620]
3	1050 [565]
4	1100 [595]
6 and 6F	1100 [595]
7 and 7M	1100 [595]
16	1200 [650]

5.5.1 Grade 6 and 6F nuts shall be tempered for a minimum of 1 h at the temperature.

5.6 Grades 8, 8C, 8M, 8T, 8F, 8P, 8N, 8MN, 8R, 8S, 8LN, 8MLN, and 8MLCuN nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled or cold-drawn bars.

5.7 Grades 8A, 8CA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8RA, 8SA, 8LNA, 8MLNA, and 8MLCuNA nuts shall be hot or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and the nuts shall subsequently be carbide-solution treated by heating them for a sufficient time at a temperature to dissolve chromium carbides followed by cooling at a rate sufficient to prevent reprecipitation of the carbides.

6. Chemical Composition

6.1 An analysis of each heat of steel used for nuts shall be made by the manufacturer during the pouring of the steel. For strand cast materials, the requirements of 8.2 and 8.3 of Specification A 788 shall be met. Should the purchaser deem it necessary to have the transition zone of two heats sequentially cast discarded, the purchaser shall invoke Supplementary Requirement S3 of Specification A 788.

6.2 The heat analysis of the nut materials shall conform to the chemical composition requirements for the grade ordered as specified in Table 1. Nuts that are normally furnished from stock are not identified by heat number, and thus heat analysis cannot normally be reported to the purchaser. (See Supplementary Requirement S2.) Supplementary Requirement S6 is provided for use when heat analysis control is required.

6.3 Steels with added lead shall not be used.

6.4 Product analyses may be made by the purchaser from a sample nut selected by the purchaser or the purchaser's representative from each item in the shipment which shall meet the product analysis requirements for the grade ordered in Table 1. Product analysis tolerances are found in Tables 5 and 6 of Specification A 29/A 29M, and Table 1 of Specification A 484/A 484M.

6.5 A starting material that specifically requires the addition of any element beyond those listed in Table 1 is not permitted. This does not preclude the use of deoxidizers.

6.6 Chemical analysis shall be performed in accordance with Test Methods A 751.

7. Mechanical Requirements

7.1 *Hardness Test:*

7.1.1 *Requirements:*

7.1.1.1 All nuts shall be capable of meeting the hardness requirements specified in Table 2.

7.1.1.2 Sample nuts of Grades 1, 2, 2H, 2HM, 3, 4, 7, 7M, and 16 which have been given the treatment described in 7.1.5.2 shall meet the minimum hardness specified in Table 2.

7.1.2 *Number of Tests* (Grades 1, 2, 2H, 3, 4, 7, and 16 and all types of Grade 6):

7.1.2.1 Tests on the number of sample nuts in accordance with the following table shall be performed in accordance with 7.1.5.1 by the manufacturer following all production heat treatments:

Lot Size	Samples
Up to 800	1
801 to 8000	2
8001 to 22 000	3
Over 22 000	5

7.1.2.2 In addition, a hardness test shall be performed by the manufacturer in accordance with 7.1.5.2 on one sample nut selected from each nominal diameter and series from each grade and heat number following completion of all production heat treatments.

7.1.3 *Number of Tests, Grades 2HM and 7M:*

7.1.3.1 The maximum hardness of Grade 2HM and 7M shall be 235 HB or 99 HRB (conversion in accordance with Table 2B of Test Methods and Definitions A 370). Conformance to the maximum hardness shall be insured by testing the hardness of each nut by Brinell or Rockwell B methods as described in the sections on Brinell Test, Portable Hardness Test, and Rockwell Test of Test Methods and Definitions A 370. Surface preparation for hardness testing shall be in accordance with Test Methods E 18. Product which has been 100% tested and found acceptable shall have a line under the "M."

7.1.3.2 In addition, 7.1.2.2 shall be met.

7.1.4 *Number of Tests, All Types of Grade 8* — Tests on the number of sample nuts in accordance with 7.1.2.1 shall be performed in accordance with 7.1.5.1 by the manufacturer.

7.1.5 *Test Methods:*

7.1.5.1 *Test 1* — The manufacturer shall perform the hardness tests in accordance with Annex A3, Paragraph A3.5.2 of Test Methods and Definitions A 370.

7.1.5.2 *Test 2* — The manufacturer shall perform hardness tests in accordance with 7.1.5.1 to sample nuts after the following test heat treatment. After completion of all production heat treatments heat the specimen nuts to the temperatures indicated below for 24 h, then slow cool. Test at room temperature.

Grade	Temperature °F [°C]
1	850 [455]
2, 2H, 2HM	1000 [540]
3, 4, 7, 7M	1100 [590]
16	1200 [650]

7.1.5.3 *Special Requirement, Grades 2HM and 7M* — Preparation of Grades 2HM and 7M nuts for hardness test and the hardness test itself shall be performed with consideration to *(1)* protect legibility of markings; *(2)* minimize exterior dimensional changes; and *(3)* maintain thread fit.

7.2 *Proof Load Test:*

7.2.1 *Requirements* — All nuts shall be capable of withstanding the proof loads specified in Table 3. However, nuts manufactured to dimensions and configurations other than those covered by ANSI B1.1 and B18.2.2 are not subject to the proof load test.

7.2.2 *Number of Tests:*

7.2.2.1 Tests on the number of sample nuts in accordance with 7.1.2.1 shall be performed by the manufacturer following all production heat treatments except that, unless proof load testing or Supplementary Requirement S1 is specified in the order, nuts which would require a proof load in excess of 120 000 lbf [530 kN] may be furnished on the basis of minimum hardness requirements. Proof load testing of nuts requiring a proof load of over 120 000 lbf [530 kN] is covered in Supplementary Requirement S5.

7.2.3 *Test Method* — The test shall be in accordance with Annex A3, Paragraph A3.5.1, of Test Methods and Definitions A 370.

7.3 *Cone Proof Load Test:*

7.3.1 *Requirements* — This test shall be performed only when visible surface discontinuities become a matter of issue between the manufacturer and the purchaser. The requirements specified in Table 4 shall be met for the size range $\frac{1}{4}$ to $1\frac{1}{2}$ in. [6.4 to 38.1 mm]. Nuts not in this size range and all types of Grade 8 nuts are not subject to this test. Also, nuts manufactured to dimensions and configurations other than those covered by ANSI B1.1 and B18.2.2 are not subject to the cone proof load test.

7.3.2 *Number of Tests* — Sample nuts in accordance with 7.1.2.1 shall be tested by the manufacturer.

7.3.3 *Test Method* — The test shall consist of assembling a hardened cone (see Fig. 1) and the nut to be tested on a hardened steel mandrel, and applying the proof load specified in Table 4. The mandrel shall conform to the requirements of Annex A3, Paragraph A3.5.1 of Test Methods and Definitions A 370 except that the threads shall be in accordance with ANSI B1.1 of the appropriate thread series, Class 3A fit. The hardened cone shall be as described in Fig. 2. The lot shall be considered acceptable if the sample nut withstands application of the proof load without failure.

8. Retests

8.1 Provisions for retests by the purchaser and his representative are specified in Supplementary Requirement S3.

9. Dimensions

9.1 Nuts shall be hexagonal in shape, and in accordance with the dimensions for the hex or heavy hex series, as required, by ANSI B18.2.2. Unless otherwise specified, the American National Standard Heavy Hex Series shall be used and nuts shall be either double chamfered or have a machined or forged washer face, at the option of the manufacturer, and, conform to the angularity requirements of ANSI B18.2.2.

9.2 Unless otherwise specified, threads shall be in accordance with ANSI B1.1 and shall be gaged in accordance with ANSI B1.2 as described in 9.2.1 and 9.2.2.

9.2.1 Nuts up to and including 1 in. [25.4 mm] nominal size shall be UNC Series Class 2B fit.

9.2.2 Nuts over 1 in. [25.4 mm] nominal size shall be either UNC Series Class 2B fit or 8 UN Series Class 2B fit. Unless otherwise specified, the 8 UN series shall be furnished.

10. Workmanship, Finish, and Appearance

10.1 Nuts shall be free of defects and shall be good commercial finish.

10.2 If visible surface imperfections in size $\frac{1}{4}$ thru $1\frac{1}{2}$ in. [6.4 thru 38.1 mm] and in any grade other than Grade 8 become a matter of issue between the manufacturer and the purchaser, the cone proof load test described in 7.3 shall be employed.

10.3 If a scale-free bright finish is required, this shall be specified on the purchase order.

11. Inspection

11.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless agreed otherwise.

12. Rejection

12.1 Unless otherwise specified, any rejection based on tests made in accordance with 6.4 shall be reported to the manufacturer within 30 days from the date of tests.

13. Certification

13.1 When agreed upon in writing between the manufacturer and the purchaser, a certification that the nuts were manufactured and tested in accordance with this specification may be the basis of acceptance of the nuts.

13.2 When specified on the order, the manufacturer shall supply a test report showing the results of the mechanical and/or macroetch inspection tests performed in accordance with this specification. The specification designation included on test reports shall include year of issue and revision letter, if any.

13.3 When required in the order, the chemical analysis requirements and the minimum tempering temperature for nuts of Grades 2H, 2HM, 3, 4, 6, 6F, 7, and 7M shall be furnished on the certification. See 6.2 for heat analysis identification. (See Supplementary Requirement S2.)

14. Product Marking

14.1 All nuts shall bear the manufacturer's identification mark.

14.2 Nuts shall be legibly marked to indicate the grade and the process of the manufacturer, as prescribed in Table 5.

14.3 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

14.4 *Bar Coding* — In addition to the requirements in 14.1, 14.2, and 14.3, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard B-5 02.00. If used on small items, the bar code may be applied to the box or a substantially applied tag.

15. Keywords

15.1 bolting; chemical analysis; marking on fasteners

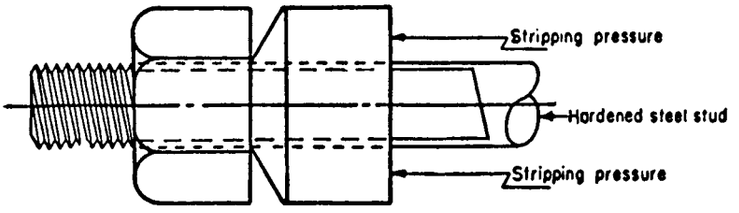


FIG. 1 APPLICATION OF HARDENED STEEL CONE TO TESTING OF NUTS

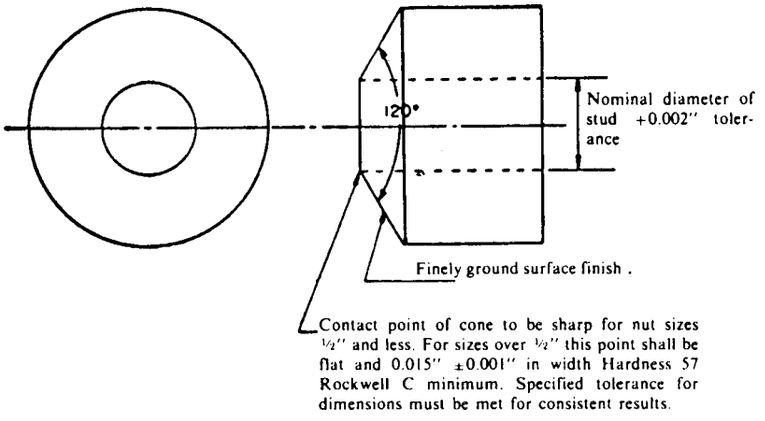


FIG. 2 HARDENED STEEL CONE

TABLE 1
CHEMICAL REQUIREMENTS [NOTES (1), (2)]

Grade Symbol	Material	Carbon, %	Manganese, %	Phosphorus, %	Sulfur, % [Note (3)]	Silicon, %	Chromium, %	Nickel, %	Molybdenum, %	Titanium, %	Columbium and Tantalum, %	Selenium, %	Other Elements, %
1	carbon	0.15 min	1.00 max	0.040 max	0.050 max	0.40 max	...	...	...	...	...	...	...
2, 2HM, and 2H	carbon	0.40 min	1.00 max	0.040 max	0.050 max	0.40 max	...	...	...	...	...	...	...
4	carbon, molybdenum	0.40–0.50	0.70–0.90	0.035 max	0.040 max	0.15–0.35	...	...	0.20–0.30	...	...	...	...
3	AISI 501	0.10 min	1.00 max	0.040 max	0.030 max	1.00 max	4.0–6.0	...	0.40–0.65	...	...	...	...
6	AISI 410	0.15 max	1.00 max	0.040 max	0.030 max	1.00 max	11.5–13.5	...	...	...	...	...	...
6F	AISI 416 with sulfur	0.15 max	1.25 max	0.060 max	0.15 min	1.00 max	12.0–14.0	...	...	...	...	...	...
6F	AISI 416 with selenium	0.15 max	1.25 max	0.060 max	0.060 max	1.00 max	12.0–14.0	...	...	...	...	0.15 min	...
7, 7M	AISI 4140/4142/4145, 4140H, 4142H, 4145H	0.37–0.49	0.65–1.10	0.04 max	0.04 max	0.15–0.35	0.75–1.20	...	0.15–0.25	...	...	...	...
8, 8A	AISI 304	0.08 max	2.00 max	0.045 max	0.030 max	1.00 max	18.0–20.0	8.0–10.5	...	...	...	...	...
8C, 8CA	AISI 347	0.08 max	2.00 max	0.045 max	0.030 max	1.00 max	17.0–19.0	9.0–13.0	...	...	10 × carbon content, min	...	...
8M, 8MA	AISI 316	0.08 max	2.00 max	0.045 max	0.030 max	1.00 max	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	...
8T, 8TA	AISI 321	0.08 max	2.00 max	0.045 max	0.030 max	1.00 max	17.0–19.0	9.0–12.0	...	5 × carbon content, min	...	...	...
8F, 8FA	AISI 303 with sulfur	0.15 max	2.00 max	0.20 max	0.15 min	1.00 max	17.0–19.0	8.0–10.0	...	...	...	...	
8F, 8FA	AISI 303 with selenium	0.15 max	2.00 max	0.20 max	0.06 max	1.00 max	17.0–19.0	8.0–10.0	...	...	...	0.15 min	...
8P, 8PA	AISI 305 with restricted carbon	0.08 max	2.00 max	0.045 max	0.030 max	1.00 max	17.0–19.0	10.5–13.0	...	...	...	...	...
8N, 8NA	AISI 304N	0.08 max	2.00 max	0.045 max	0.030 max	1.00 max	18.0–20.0	8.0–10.5	...	...	...	...	Nitrogen, 0.10–0.16
8LN, 8LNA	AISI 304N with restricted carbon	0.030 max	2.00 max	0.045 max	0.030 max	1.00 max	18.0–20.0	8.0–10.5	...	...	...	...	Nitrogen, 0.10–0.16
8MN, 8MNA	AISI 316N	0.08 max	2.00 max	0.045 max	0.030 max	1.00 max	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	Nitrogen, 0.10–0.16

TABLE 1 (CONT'D)
CHEMICAL REQUIREMENTS [NOTES (1), (2)]

Grade Symbol	Material	Carbon, %	Manganese, %	Phosphorus, %	Sulfur, % [Note (3)]	Silicon, %	Chromium, %	Nickel, %	Molybdenum, %	Titanium, %	Columbium and Tantalum, %	Selenium, %	Other Elements, %
8MLN, 8MLNA	AISI 316N with restricted carbon	0.030 max	2.00 max	0.045 max	0.030 max	1.00 max	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	Nitrogen, 0.10–0.16
8R, 8RA [Note (4)]	XM19	0.06 max	4.0–6.0	0.040 max	0.030 max	1.00 max	20.5–23.5	11.5–13.5	1.50–3.00	...	0.10–0.30	...	Nitrogen, 0.20–0.40 Vanadium, 0.10–0.30
8S, 8SA	[Note (5)]	0.10 max	7.0–9.0	0.040 max	0.040 max	3.5–4.5	16.0–18.0	8.0–9.0	...	...	...	...	Nitrogen, 0.08–0.18
8MLCuN, 8MLCuNA	S31254	0.020 max	1.00 max	0.030 max	0.010 max	0.80 max	19.5–20.5	17.5–18.5	6.0–6.5	...	...	...	Nitrogen, 0.18–0.22 Copper, 0.50–1.00
16	Chromium Molybdenum Vanadium	0.36–0.47	0.45–0.70	0.035 max	0.040 max	0.15–0.35	0.80–1.15	...	0.50–0.65	...	...	...	Vanadium 0.25–0.35

NOTES:
(1) The intentional addition of Bi, Se, Te, and Pb is not permitted except for Grades 6F, 8F, and 8FA, in which Se is specified and required.
(2) Product Analysis—Individual determinations sometimes vary from the specified limits on ranges as shown in the table. The several determinations of any individual element in a heat may not vary both above or below the specified range. Product analysis tolerances may be found in Tables 5 and 6 of Specification A 29/A 29M, and Table 1 of Specification A 484/A 484M.
(3) Because of the degree to which sulfur segregates, product analysis for sulfur over 0.060 % max is not technologically appropriate.
(4) As described in Specification A 276.
(5) Similar to grade S21800 of Specification A 276, except phosphorus is restricted to 0.040 % max.

TABLE 2
HARDNESS REQUIREMENTS

Grade and Type	Completed Nuts			Sample Nut after Treatment as in 7.1.5.2	
		Rockwell Hardness			
	Brinell Hardness	C Scale	B Scale	Brinell Hardness, min	Rockwell Hardness B Scale, min
1	121 min	...	70 min	121	70
2	159 to 352	...	84 min	159	84
2H	248 to 352	24 to 38	...	179	89
To 1½ in. [38.1 mm], incl	248 to 352	24 to 38	...	179	89
Over 1½ in. [38.1 mm]	212 to 352	38 max	95 min	147	79
2HM and 7M	159 to 237	22 max	...	159	84
3, 4, 7, and 16	248 to 352	24 to 38	...	201	94
6 and 6F	228 to 271	20 to 28	...	...	...
8, 8C, 8M, 8T, 8F, 8P, 8N,	126 to 300	...	60 to 105	...	...
8MN, 8LN, 8MLN, and 8MLCuN	126 to 300	...	60 to 105	...	...
8A, 8CA, 8MA, 8TA,	126 to 192	...	60 to 90	...	...
8FA, 8PA, 8NA, 8MNA,	126 to 192	...	60 to 90	...	...
8LNA, 8MLNA, and 8MLCuNA	126 to 192	...	60 to 90	...	...
8R, 8RA, 8S, and 8SA	183 to 271	B 88 to C25	...	...	...

TABLE 3
PROOF LOAD USING THREADED MANDREL

Nominal Size, in. [mm]	Threads per inch [25.4 mm]	Stress Area, in.^{2}, [mm^2]	Proof Load, lbf [kN] [Note (1)]					
			Grade 1		Grades 2, 2HM, 6 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex [Note (2)]	Hex [Note (3)]	Heavy Hex [Note (4)]	Hex [Note (5)]	Heavy Hex [Note (6)]	Hex [Note (7)]
1/4 [6.4]	20	0.0316 [20.4]	4 130 [18.4]	3 820 [17.0]	4 770 [21.2]	4 300 [19.1]	5 570 [24.8]	4 770 [21.2]
5/16 [7.9]	18	0.0524 [33.8]	6 810 [30.3]	6 290 [28.0]	7 860 [35.0]	7 070 [31.4]	9 170 [40.8]	7 860 [35.0]
3/8 [9.5]	16	0.0774 [49.9]	10 080 [44.8]	9 300 [41.4]	11 620 [51.7]	10 460 [46.5]	13 560 [60.3]	11 620 [51.7]
7/16 [11.1]	14	0.1063 [68.6]	13 820 [61.5]	12 760 [56.8]	15 940 [70.9]	14 350 [63.8]	18 600 [82.7]	15 940 [70.9]
1/2 [12.7]	13	0.1419 [91.5]	18 450 [82.1]	17 030 [75.8]	21 280 [94.6]	19 160 [85.2]	24 830 [110]	21 280 [94.6]
9/16 [14.2]	12	0.182 [117]	23 660 [105]	21 840 [97.1]	27 300 [121]	24 570 [109]	31 850 [142]	27 300 [121]
5/8 [15.9]	11	0.226 [146]	29 380 [131]	27 120 [121]	33 900 [151]	30 510 [136]	39 550 [176]	33 900 [151]
3/4 [19]	10	0.334 [215]	43 420 [193]	40 080 [178]	50 100 [223]	45 090 [200]	58 450 [260]	50 100 [223]
7/8 [22.2]	9	0.462 [298]	60 060 [267]	55 440 [247]	69 300 [308]	62 370 [277]	80 850 [360]	69 300 [308]
1 [25.4]	8	0.606 [391]	78 780 [350]	72 720 [323]	90 900 [404]	81 810 [364]	106 000 [472]	90 900 [404]
1 1/8 [28.6]	8	0.790 [510]	102 700 [457]	94 800 [422]	118 500 [527]	106 700 [475]	138 200 [615]	118 500 [527]
1 1/4 [31.8]	8	1.000 [645]	130 000 [578]	120 000 [534]	150 000 [667]	135 000 [600]	175 000 [778]	150 000 [667]
1 3/8 [34.9]	8	1.233 [795]	160 200 [713]	148 000 [658]	185 000 [823]	166 500 [741]	215 800 [960]	185 000 [823]
1 1/2 [38.1]	8	1.492 [962]	194 000 [863]	170 040 [756]	223 800 [996]	201 400 [896]	261 100 [1161]	223 800 [996]

			All Types of Grade 8	
			Heavy Hex [Note (8)]	Hex [Note (9)]
1/4 [6.4]	20	0.0316 [20.4]	2 540 [11.3]	2 380 [10.6]
5/16 [7.9]	18	0.0524 [33.8]	4 190 [18.6]	3 930 [17.5]
3/8 [9.5]	16	0.0774 [49.9]	6 200 [27.6]	5 810 [25.8]
7/16 [11.1]	14	0.1063 [68.6]	8 500 [37.8]	7 970 [35.4]
1/2 [12.7	13	0.1419 [91.5]	11 350 [50.5]	10 640 [49.8]
9/16 [14.2]	12	0.182 [117]	14 560 [64.8]	13 650 [60.7]
5/8 [15.9]	11	0.226 [146]	18 080 [80.4]	16 950 [75.4]
3/4 [19]	10	0.334 [215]	26 720 [119]	25 050 [111]
7/8 [22.2]	9	0.462 [298]	36 960 [164]	34 650 [154]
1 [25.4]	8	0.606 [391]	48 480 [216]	45 450 [202]
1 1/8 [28.6]	8	0.790 [510]	63 200 [281]	59 250 [264]
1 1/4 [31.8]	8	1.000 [645]	80 000 [356]	75 000 [334]
1 3/8 [34.9]	8	1.233 [795]	98 640 [439]	92 450 [411]
1 1/2 [38.1]	8	1.492 [962]	119 360 [531]	111 900 [498]

GENERAL NOTE—Proof loads are not design loads.

NOTES:
(1) See limit for proof load test in 7.2.2.1. The proof load for jam nuts shall be 46% of the tabulated load.
(2) Based on proof stress of 130 000 psi [895 MPa].
(3) Based on proof stress of 120 000 psi [825 MPa].
(4) Based on proof stress of 150 000 psi [1035 MPa].
(5) Based on proof stress of 135 000 psi [930 MPa].
(6) Based on proof stress of 175 000 psi [1205 MPa].
(7) Based on proof stress of 150 000 psi [1035 MPa].
(8) Based on proof stress of 80 000 psi [550 MPa].
(9) Based on proof stress of 75 000 psi [515 MPa].

TABLE 4
PROOF LOAD USING 120° HARDENED STEEL CONE [NOTE (1)]

Nominal Size, in. [mm]	Threads per inch [25.4 mm]	Stress Area, in.^{2}, [mm^2]	Proof Load, lbf [kN]					
			Grade 1		Grades 2, 2HM, 6 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex [Note (2)]	Hex [Note (3)]	Heavy Hex [Note (4)]	Hex [Note (5)]	Heavy Hex [Note (6)]	Hex [Note (4)]
1/4 [6.4]	20	0.0318 [20.5]	3 800 [16.9]	3 550 [15.8]	4 400 [19.6]	4 000 [17.8]	5 150 [22.9]	4 400 [19.6]
5/16 [7.9]	18	0.0524 [33.8]	6 150 [27.4]	5 700 [25.4]	7 100 [31.6]	6 400 [28.5]	8 300 [36.9]	7 100 [31.6]
3/8 [9.5]	16	0.0774 [49.9]	8 950 [39.8]	8 250 [36.7]	10 300 [45.8]	9 300 [41.4]	12 000 [53.4]	10 300 [45.8]
7/16 [11.1]	14	0.1063 [68.6]	12 000 [53.4]	11 100 [49.4]	13 850 [61.6]	12 450 [55.4]	16 150 [71.8]	13 850 [61.6]
1/2 [12.7]	13	0.1419 [91.5]	15 700 [69.8]	14 500 [64.5]	18 100 [80.5]	16 300 [72.5]	21 100 [93.8]	18 100 [80.5]
9/16 [14.2]	12	0.182 [117]	19 650 [87.4]	18 150 [80.7]	22 700 [101]	20 400 [90.7]	26 500 [118]	22 700 [101]
5/8 [15.9]	11	0.226 [146]	23 900 [106]	22 050 [98.1]	27 550 [123]	24 800 [110]	32 150 [143]	27 550 [123]
3/4 [19]	10	0.334 [215]	33 650 [150]	31 050 [138]	38 850 [173]	34 950 [155]	45 300 [202]	38 850 [173]
7/8 [22.2]	9	0.462 [298]	44 300 [197]	40 900 [182]	51 100 [227]	46 600 [207]	59 650 [265]	51 100 [227]
1 [25.4]	8	0.606 [391]	55 150 [245]	50 900 [226]	63 650 [283]	57 300 [255]	74 250 [330]	63 650 [283]
1 1/8 [28.6]	8	0.790 [510]	68 000 [302]	62 800 [279]	78 500 [349]	70 650 [314]	91 600 [407]	78 500 [349]
1 1/4 [31.8]	8	1.000 [645]	81 250 [361]	75 000 [334]	93 750 [417]	84 400 [375]	109 350 [486]	93 750 [417]
1 3/8 [34.9]	8	1.233 [795]	94 250 [419]	86 950 [387]	108 750 [484]	97 800 [435]	126 850 [564]	108 750 [484]
1 1/2 [38.1]	8	1.492 [962]	106 700 [475]	98 500 [438]	123 100 [548]	110 800 [493]	143 600 [639]	123 100 [548]

NOTES:
(1) Based upon following equation (this equation cannot be used for extrapolating values beyond the size ranges listed in this table):

$$CPL = (1 - 0.30D) \times f \times As$$

where:
CPL = cone stripping proof load lbf [kN],
D = nominal diameter of nut, in. [mm],
f = minimum proof stress of nut, psi [MPa]; see [Notes (2),(3),(4),(5),(6)],
As = tensile stress area of nut, in.^{2} = $0.7854\,[D - 0.9743/n]^2$, and
n = threads per inch [25.4 mm].
(2) Based on proof stress of 130 000 psi [895 MPa].
(3) Based on proof stress of 120 000 psi [825 MPa].
(4) Based on proof stress of 150 000 psi [1035 MPa].
(5) Based on proof stress of 135 000 psi [930 MPa].
(6) Based on proof stress of 175 000 psi [1205 MPa].

TABLE 5 98
MARKING OF NUTS

Grade and Type	Nuts Hot-Forged or Cold-Punched	Nuts Machined from Bar Stock	Nuts Manufactured in Accordance with 5.7
1	1	1B	...
2	2	2B	...
2H [Note (1)]	2H	2HB	...
2HM [Note (1)]	2HM	2HMB	...
3	3	3B	...
4	4	4B	...
4L [Note (2)]	4L	4BL	...
6	6	6B	...
6F	6F	6FB	...
7	7	7B	...
7L [Note (2)]	7L	7BL	...
7M [Note (1)]	7M	7MB	...
8	8	8B	8A
8C	8C	8CB	8CA
8M	8M	8MB	8MA
8T	8T	8TB	8TA
8F	8F	8FB	8FA
8P	8P	8PB	8PA
8N	8N	8NB	8NA
8MN	8MN	8MNB	8MNA
8R	8R	8RB	8RA
8S	8S	8SB	8SA
8LN	8LN	8LNB	8LNA
8MLN	8MLN	8MLNB	8MLNA
8MLCuN	8MLCuN	8MLCuNB	8MLCuNA
16	16	16B	

NOTES:
(1) The letters H and M indicate heat-treated nuts (see Section 5).
(2) See Supplementary Requirement S4.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Strain-Hardened Austenitic Steel Nuts

S1.1 Strain hardened Grades 8, 8C, 8T, 8M, 8F, 8P, 8N, or 8MN nuts may be specified. When Supplementary Requirement S1 is invoked in the order, nuts shall be machined from cold drawn bars or shall be cold forged to shape. No subsequent heat treatment shall be performed on the nuts. Nuts made in accordance with this requirements shall be proof load tested in accordance with 7.2.2.1 and shall withstand the proof load specified in Table S1.1. For nut requiring proof loads over 120 000 lbf [530 kN], Supplementary Requirement S5 is invoked. The hardness limits of Table 2 do not apply to strain hardened nuts. Nuts made in accordance with this requirement shall be marked with the Grade symbol underlined.

S2. Chemical Composition Certification

S2.1 The purchaser shall be provided with a statement certifying that the nuts meet the chemical composition requirements specified in Table 1.

S3. Retests by Purchaser's Representative

S3.1 The purchaser's representative may select two nuts per keg (200-lb unit [90-kg]) for sizes $\frac{5}{8}$ in. [15.9 mm] and smaller, one nut per keg for sizes over $\frac{5}{8}$ in. [15.9 mm] up to and including $1\frac{1}{2}$ in. [38.1 mm], and one nut per every two kegs for sizes larger than $1\frac{1}{2}$ in. [38.1 mm], which shall be subjected to the tests specified in Section 7.

S4. Low-Temperature Requirements for (Grade 4 or) Grade 7 Nuts

S4.1 When low-temperature requirements are specified for Grade 4 or Grade 7 nuts, the Charpy test procedures and requirements as defined in Specification A 320 for Grade L7 shall apply. Depending on the size of nuts, separate test samples of the same heat may be required and shall be processed through heat treatment with the nuts for which the test is to apply. Full-size impact specimens cannot be obtained if the bar stock is smaller than $\frac{5}{8}$ in. in diameter.

S4.2 An "L" shall be added to the marking, as shown in Table 5, for nuts so tested. 98

S5. Proof Load Tests of Large Nuts

S5.1 Proof load testing of nuts requiring proof loads of over 120 000 lbf [530 kN] may be required. When specified, the test is to be performed in accordance with 7.2 to the loads required by Table S5.1. The maximum load will be based entirely on the equipment available.

S6. Control of Product by Heat Number

S6.1 When control of nuts by actual heat analysis is required and this supplementary requirement is specified, the manufacturer shall identify the completed nuts in each shipment by the actual heat number. When this supplementary requirement is specified, a certificate including the results of the actual production tests of each test lot together with the heat chemical analysis shall be furnished by the manufacturer.

TABLE S1.1
PROOF LOAD TESTING OF STRAIN HARDENED NUTS USING THREADED MANDREL

Nominal Size, in. [mm]	Threads per in. [25.4 mm]	Stress Area, in.^{2}, [mm^2]	Proof load, lbf [kN] [Note (1)] Grade 8M (strain hardened) Heavy Hex [Note (2)]	Grade 8M (strain hardened) Hex [Note (3)]	All Other Types of Grade 8 (strain hardened) Heavy Hex [Note (4)]	All Other Types of Grade 8 (strain hardened) Hex [Note (2)]
1/4 [6.4]	20	0.0316 [20.4]	3 480 [15.5]	3 160 [14.0]	3 950 [17.6]	3 480 [15.5]
5/16 [7.9]	18	0.0523 [33.8]	5 760 [25.6]	5 240 [23.3]	6 550 [29.1]	5 760 [25.6]
3/8 [9.5]	16	0.0774 [49.9]	8 510 [37.8]	7 740 [34.4]	9 675 [43.0]	8 510 [37.8]
7/16 [11.1]	14	0.1063 [68.6]	11 690 [52.0]	10 630 [47.3]	13 290 [59.1]	11 690 [52.0]
1/2 [12.7]	13	0.1419 [91.5]	15 610 [69.4]	14 190 [63.1]	17 740 [78.9]	15 610 [69.4]
9/16 [14.2]	12	0.182 [117]	20 020 [89.0]	18 200 [80.9]	22 750 [101]	20 020 [89.0]
5/8 [15.9]	11	0.226 [146]	24 860 [110]	22 600 [100]	28 250 [126]	24 860 [110]
3/4 [19]	10	0.334 [215]	36 740 [163]	33 400 [148]	41 750 [186]	36 740 [163]
7/8 [22.2]	9	0.462 [298]	46 200 [206]	41 580 [185]	53 130 [236]	46 200 [206]
1 [25.4]	8	0.606 [391]	60 600 [270]	54 540 [243]	69 690 [310]	60 600 [270]
1 1/8 [28.6]	8	0.790 [510]	75 050 [334]	67 150 [299]	82 950 [369]	75 050 [334]
1 1/4 [31.8]	8	1.000 [645]	95 000 [422]	85 000 [378]	105 000 [467]	95 000 [422]
1 3/8 [34.9]	8	1.233 [795]	110 970 [494]	98 640 [439]	123 300 [548]	110 970 [494]
1 1/2 [38.1]	8	1.492 [962]	134 280 [597]	119 360 [531]	149 200 [664]	134 280 [597]

GENERAL NOTE—Proof loads are not design loads.

NOTES:
(1) The proof load for jam nuts shall be 46% of the tabulated value.
(2) Based on proof stress of 110 000 psi [760 MPa] up to 3/4 in. [19 mm]; 100 000 psi [690 MPa] 7/8 to 1 in. [22.2 to 25.4 mm]; 95 000 psi [655 MPa] 1 1/8 to 1 1/4 in. [28.6 to 31.8 mm]; 90 000 psi [620 MPa] 1 3/8 to 1 1/2 in. [34.9 to 38.1 mm].
(3) Based on proof stress of 100 000 psi [690 MPa] up to 3/4 in. [19 mm]; 90 000 psi [620 MPa] 7/8 to 1 in. [22.2 to 25.4 mm]; 85 000 psi [585 MPa] 1 1/8 to 1 1/4 in. [28.6 to 31.8 mm]; 80 000 psi [550 MPa] 1 3/8 to 1 1/2 in. [34.9 to 38.1 mm].
(4) Based on proof stress of 125 000 psi [860 MPa] up to 3/4 in. [19 mm]; 115 000 psi [795 MPa] 7/8 to 1 in. [22.2 to 25.4 mm]; 105 000 psi [725 MPa] 1 1/8 to 1 1/4 in. [28.6 to 31.8 mm]; 100 000 psi [690 MPa] 1 3/8 to 1 1/2 in. [34.9 to 38.1 mm].

TABLE S5.1
PROOF LOAD FOR LARGE HEAVY HEX NUTS [NOTE (1)]

Nominal Size, in. [mm]	Threads per in. [25.4 mm]	Stress Area, in.^{2} [mm^2]	Proof Load, lbf (kN) [Note (2)] Grade 1 Heavy Hex	Grades 2, 6, 6F Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
1 5/8 [41.2]	8	1.78 [1148]	231 400 [1029]	267 000 [1188]	311 500 [1386]
1 3/4 [44.4]	8	2.08 [1342]	270 400 [1203]	312 000 [1388]	364 000 [1619]
1 7/8 [47.6]	8	2.41 [1555]	313 300 [1394]	361 500 [1608]	421 800 [1876]
2 [50.8]	8	2.77 [1787]	360 100 [1602]	415 500 [1848]	484 800 [2156]
2 1/4 [57.2]	8	3.56 [2297]	462 800 [2059]	534 000 [2375]	623 000 [2771]
2 1/2 [63.5]	8	4.44 [2864]	577 200 [2568]	666 000 [2962]	777 000 [3456]
2 3/4 [69.8]	8	5.43 [3503]	705 900 [3140]	814 500 [3623]	950 250 [4227]

NOTES:
(1) ANSI B18.2.2 in the size range over 1 1/2 in. [38.1 mm] provides dimensions only for heavy hex nuts. Refer to 7.3.1.
(2) Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 3 or Table S1.1. The proof load for jam nuts shall be 46% of the tabulated load.

APPENDIX

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steel by reducing oversized bars to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar, so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening. Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined.

SPECIFICATION FOR SEAMLESS COLD-DRAWN INTERMEDIATE ALLOY-STEEL HEAT-EXCHANGER AND CONDENSER TUBES

SA-199/SA-199M

(Identical with ASTM Specification A 199/A 199M-92)

1. Scope

1.1 This specification covers several grades of minimum-wall-thickness, chromium-molybdenum and chromium-molybdenum-silicon, seamless, cold-drawn, intermediate alloy steel tubes for heat exchangers, condensers, and similar heat transfer apparatus.

1.2 The tubing sizes usually furnished to this specification are $\frac{1}{8}$ to 3 in. [3.2 to 76.2 mm] in outside diameter. Tubing having other dimensions may be furnished provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Document

2.1 *ASTM Standard:*

A 450/A 450M Specification for General Requirements for Carbon. Ferritic Alloy, and Austenitic Alloy Steel Tubes

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately.

4.1.1 Quantity (feet, metres, or number of lengths).

4.1.2 Name of material (seamless tubes),

4.1.3 Grade (Table 1),

4.1.4 Manufacture (cold drawn),

4.1.5 Size (outside diameter and minimum wall thickness),

4.1.6 Length (specific or random),

4.1.7 Chemical composition (heat or product),

4.1.8 Test report required (see Certification Section of Specification A 450/A 450M),

4.1.9 Optional requirements (of 12.5),

4.1.10 Specification designation, and

4.1.11 Special requirements.

5. Manufacture

5.1 Tubes shall be made by the seamless process and shall be cold drawn.

6. Heat Treatment

6.1 After the final cold-draw pass, Grade T-11 tubes shall be heat treated at 1200°F [650°C] or higher and all other grades except T91 shall be heat treated at 1250°F [675°C] or higher. For Grade T91, the tubes shall be normalized from the temperature range of 1900–2000°F [1400–1095°C] and tempered at 1305°F (730°C) minimum.

7. Surface Condition

7.1 The tubes shall be free of scale. A slight amount of oxidation will not be considered as scale.

8. Chemical Composition

8.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

9. Product Analysis

9.1 An analysis shall be made of one billet or tube from each heat. The chemical composition thus determined shall conform to the requirements specified.

9.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 1) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes that do not meet the requirements of the specification shall be rejected.

NOTE 1 — For flattening and flaring requirements, the term "lot" applies to all tubes prior to cutting, of the same nominal size and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 3.

NOTE 2 — For tension and hardness test requirements, the term "lot" applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

11. Hardness Requirements

11.1 The tubes fabricated from Grades T3b, T4, T5, T11, T21, and T22 shall have a hardness number not exceeding 85 HRB. For tubes fabricated from Grade T9, the maximum hardness shall be 89 HRB and for Grade T91 the maximum hardness shall be 98 HRB.

12. Mechanical Tests Required

12.1 *Tension Test* — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 2).

12.2 *Flattening Test* — One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring test, from each lot (Note 1).

12.3 *Flaring Test* — One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

12.4 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 2).

12.5 *Hydrostatic Test* — Each tube shall be subjected to the hydrostatic test, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include the name and order number of the purchaser.

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %							
Grade	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Others
T4	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50–1.00	2.15–2.85	0.44–0.65	. . .
T5	0.15 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	. . .
T9	0.15 max	0.30–0.60	0.025	0.025	0.25–1.00	8.00–10.00	0.90–1.10	. . .
T11	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50–1.00	1.00–1.50	0.44–0.65	. . .
T21	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50 max	2.65–3.35	0.80–1.06	. . .
T22	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50 max	1.90–2.60	0.87–1.13	. . .
T91	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.00–9.50	0.85–1.05	Ni 0.40 max; V 0.18–0.25; Cb 0.06–0.10; N 0.03–0.07; Al 0.04 max

TABLE 2
TENSILE REQUIREMENTS

	All Grades Except T91	Grade T91
Tensile strength, min., ksi [MPa]	60 [415]	85 [585]
Yield strength, min., ksi [MPa]	25 [170]	60 [415]
Elongation in 2 in., or 50 mm, min., %	30	20
For longitudinal strip tests a deduction shall be made for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points	1.50[1]	1.00[1]
When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimen with the gage length equal to 4*D* (four times the diameter) is used	22	

NOTES:
(1) The following table gives the computed minimum values.
(2) Calculated elongation requirements shall be rounded to the nearest whole number.

Wall Thickness, in. [mm]	Elongation in 2 in.,	or 50 mm, min., %[2]
$\frac{5}{16}$ (0.312) [8]	30	20
$\frac{9}{32}$ (0.281) [7.2]	28	19
$\frac{1}{4}$ (0.250) [6.4]	27	18
$\frac{7}{32}$ (0.219) [5.6]	26	17
$\frac{3}{16}$ (0.188) [4.8]	24	16
$\frac{5}{32}$ (0.156) [4]	23	15
$\frac{1}{8}$ (0.125) [3.2]	21	14
$\frac{3}{32}$ (0.094) [2.4]	20	13
$\frac{1}{16}$ (0.062) [1.6]	18	12
0.062 to 0.035 [1.6 to 0.9], excl	17	12
0.035 to 0.022 [0.9 to 0.6], excl	16	11
0.022 to 0.015 [0.6 to 0.4], incl	16	11

GENERAL NOTE: The above table gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

For all Grades except T91: $E = 48t + 15.00$
[$E = 1.87t + 15.00$]
For Grade T91: $E = 32t + 10.00$

where
E = elongation in 2 in., or 50 mm, % and
t = actual thickness of specimen, in. [mm]

TABLE 3
NUMBER OF TUBES IN A LOT HEAT
TREATED BY THE CONTINUOUS PROCESS

Side of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, CHROMIUM-MANGANESE-SILICON

SA-202/SA-202M

(Identical to ASTM Specification A 202/A 202M-93)

1. Scope

1.1 This specification covers chromium-manganese-silicon alloy steel plates, intended particularly for welded boilers and other pressure vessels.

1.2 Material under this specification is available in two grades having strength levels as follows:

Grade	Tensile Strength, ksi [MPa]
A	75-95 [515-655]
B	85-110 [585-760]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification to 2 in. [50 mm].

1.4 Grade A is suitable for rivets and when so used the bars shall be subject to the requirements for rolled bars specified in Specification A 31, except for the chemical and mechanical requirements.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 31 Specification for Steel Rivets and Bars for Rivets, Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the basis of purchase that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed.

5. Heat Treatment

5.1 Plates are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1.

7. Mechanical Requirements

7.1 *Tension Test Requirements* — The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %	
Elements	Grade A	Grade B
Carbon, max[A]	0.17	0.25
Manganese:		
Heat analysis	1.05–1.40	1.05–1.40
Product analysis	0.97–1.52	0.97–1.52
Phosphorus, max[A]	0.035	0.035
Sulfur, max[A]	0.035	0.035
Silicon:		
Heat analysis	0.60–0.90	0.60–0.90
Product analysis	0.54–0.96	0.54–0.96
Chromium:		
Heat analysis	0.35–0.60	0.35–0.60
Product analysis	0.31–0.64	0.31–0.64

[A] Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

	Grade A	Grade B
	ksi [MPa]	ksi [MPa]
Tensile strength	75–95 [515–655]	85–110 [585–760]
Yield strength, min[B]	45 [310]	47 [325]
Elongation in 8 in. [200 mm], min, %	16[A]	15[A]
Elongation in 2 in. [50 mm], min, %	19	18

[A] See Specification A 20/A 20M for elongation adjustments.
[B] Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M, and

S14. Bend Test.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, NICKEL

SA-203/SA-203M

(Identical with ASTM Specification A 203/A 203M-93)

1. Scope

1.1 This specification covers nickel-alloy steel plates intended primarily for welded pressure vessels.

1.2 Plates under this specification are available with four strength levels and two nickel compositions as follows:

Grade	Nominal Nickel Content %	Yield Strength, min, ksi [MPa]	Tensile Strength, min, ksi [MPa]
A	2.25	37 [255]	65 [450]
B	2.25	40 [275]	70 [485]
D	3.50	37 [255]	65 [450]
E	3.50	40 [275]	70 [485]
F	3.50		
2 in. [50 mm] and under		55 [380]	80 [550]
Over 2 in. [50 mm]		50 [345]	75 [515]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements. However, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

Grade	Maximum Thickness, in. [mm]
A	6[150]
B	6[150]
D	4[100]
E	4[100]
F	4[100]

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 *ASTM Standards*:

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of imperfections, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the basis of purchase that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examina-

tion is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed.

5. Heat Treatment

5.1 All plates shall be thermally treated as follows:

5.1.1 All plates of Grades A, B, D, and E shall be normalized except as permitted by 5.1.1.1

5.1.1.1 If approved by the purchaser for Grades A, B, D, and E, cooling rates faster than air cooling are permissible for improvement of the toughness, provided the plates are subsequently tempered at not less than 1100°F [595°C] for not less than ½ h.

5.1.2 All plates of Grade F shall be heat treated by heating into the austenitic range, quenching in water, and tempering at not less than 1100°F [595°C] for not less than ½ h.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements* — The material as represented by the tension test specimens shall conform to the requirements shown in Table 2.

7.1.1 For plates that have been heat treated in accordance with 5.1.1.1 or 5.1.2, and have a nominal thickness of ¾ in. [20 mm] and under, the 1½ in. (40 mm) wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation. When this specimen is used, the elongation shall be not less than 23%.

7.2 *Impact Test Requirements:*

7.2.1 Plates of Grades A, B, D, and E that have been heat treated in accordance with 5.1.1.1 shall be Charpy V-notch impact tested. The impact test shall meet 20 ft·lbf [27 J]. The test temperature and orientation shall be a matter of agreement between the purchaser and supplier.

7.2.2 Grade F plates shall be impact tested in accordance with Supplementary Requirement S5 in Specification A 20/A 20M.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %			
	Grade A	Grade B	Grade D	Grades E and F
Carbon, max[A]:				
Up to 2 in. [50 mm] in thickness	0.17	0.21	0.17	0.20
Over 2 in. to 4 in. [100 mm] incl. in thickness	0.20	0.24	0.20	0.23
Over 4 in. [100 mm] in thickness	0.23	0.25	. . .	. . .
Manganese, max:				
Heat analysis:				
2 in. [50 mm] and under	0.70	0.70	0.70	0.70
Over 2 in. [50 mm]	0.80	0.80	0.80	0.80
Product analysis				
2 in. [50 mm] and under	0.78	0.78	0.78	0.78
Over 2 in. [50 mm]	0.88	0.88	0.88	0.88
Phosphorus, max[A]	0.035	0.035	0.035	0.035
Sulfur, max[A]	0.035	0.035	0.035	0.035
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45
Nickel:				
Heat analysis	2.10–2.50	2.10–2.50	3.25–3.75	3.25–3.75
Product analysis	2.03–2.57	2.03–2.57	3.18–3.82	3.18–3.82

[A] Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

	Grades A and D		Grades B and E		Grade F	
	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]
Tensile strength						
2 in. [50 mm] and under	65–85	[450–585]	70–90	[485–620]	80–100	[550–690]
Over 2 in. [50 mm]	65–85	[450–585]	70–90	[485–620]	75–95	[515–655]
Yield strength, min						
2 in. [50 mm] and under	37	[255]	40	[275]	55	[380]
Over 2 in. [50 mm]	37	[255]	40	[275]	50	[345]
Elongation in 8 in. [200 mm] min, %[A]	19		17		. . .	
Elongation in 2 in. [50 mm] min, %[A,B]	23		21		20	

[A] See Specification A20/A 20M for elongation adjustments.
[B] See 7.1.1.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR SEAMLESS AND WELDED AUSTENITIC STAINLESS STEEL PIPES

SA-312/SA-312M

(Identical to ASTM Specification A 312/A 312M-95b except for clarified heat treatment requirements in 5.2.2.)

1. Scope

1.1 This specification covers seamless and straight-seam welded austenitic steel pipe intended for high-temperature and general corrosive service.

NOTE 1 — When the impact test criterion for a low-temperature service would be 15 ft·lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades TP304, TP304L, and TP347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3, for service at temperatures as low as −425°F [−250°C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as −325°F [−200°C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10%, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than −50°F [−45°C].

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP309Cb, TP309S, TP310Cb, TP310S, TP316, TP321, TP347, and TP348, and are intended for high-temperature service.

1.3 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.4 Table X1.1 lists the dimensions of welded and seamless stainless steel pipe as shown in ANSI B36.19. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.5 Grades TP321 and TP321H have lower strength requirements for pipe manufactured by the seamless process in nominal wall thicknesses greater than $\frac{3}{8}$ in. [9.5 mm].

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 2 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 112 Test Methods for Determining the Average Grain Size

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 381 Method of Macroetch Testing, Steel Bars, Billets, Blooms, and Forgings
E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel, and Similar Alloys
E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ANSI Standards:*
B1.20.1 Pipe Threads, General Purpose
B36.10 Welded and Seamless Wrought Steel Pipe
B36.19 Stainless Steel Pipe

2.3 *AWS Standard:*
A5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Electrodes

2.4 *Other Standard:*
SAE J1086 Practice for Numbering Metals and Alloys (UNS)

2.5 *Other Standard:*
SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

3. Ordering Information

3.1 Orders for material to this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimeters, or number of lengths),

3.1.2 Name of material (austenitic steel pipe),

3.1.3 Process (seamless or welded),

3.1.4 Grade (Table 1),

3.1.5 Size (NPS or outside diameter and schedule number or average wall thickness),

3.1.6 Length (specific or random) (Section 10),

3.1.7 End finish (Section on Ends of Specification A 530/A 530M),

3.1.8 Optional requirements (Section 7),

3.1.9 Test report required (Certification Section of Specification A 530/A 530M),

3.1.10 Specification number, and

3.1.11 Special requirements or any supplementary requirements selected, or both.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

5. Materials and Manufacture

5.1 *Manufacture:*

5.1.1 The pipe shall be made by the seamless or an automatic welding process, with no addition of filler metal in the welding operation.

5.1.2 "Welded pipe NPS 14 and smaller shall have a single longitudinal weld. Welded pipe of a size larger than NPS 14 may be produced by forming and welding two longitudinal sections of flat stock when approved by the purchaser. All weld tests, examinations, inspections, or treatments are to be performed on each weld seam."

5.1.3 At the manufacturer's option, pipe may be either hot finished or cold finished.

5.1.4 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

5.2 *Heat Treatment:*

5.2.1 All pipe shall be furnished in the heat-treated condition in accordance with the requirements of Table 2. The heat-treatment procedure, except for "H" grades, S30815, S31272, S31254, S32654, N08367, and N08904 shall consist of heating the pipe to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means.

5.2.2 All H grades shall be furnished in the solution-treated condition. For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S6).

5.3 *Grain Size:*

5.3.1 The grain size of Grade UNS S32615, as determined in accordance with Test Methods E 112, shall be No. 3 or finer.

5.3.2 The grain size of TP309H, TP309HCb, TP310H and TP310HCb, as determined in accordance with Test Methods E 112, shall be No. 6 or coarser.

5.3.3 The grain size of TP321H, as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Product Analysis

7.1 At the request of the purchaser, an analysis of one billet or one length of flat-rolled stock from each heat, or two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5	200 or fraction thereof
6 and over	100 or fraction thereof

7.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 6.

7.3 If the analysis of one of the tests specified in 7.1 does not conform to the requirements specified in Section 6, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

8. Tensile Requirements

8.1 The tensile properties of the material shall conform to the requirements prescribed in Table 3.

9. Mechanical Tests and Grain Size Determinations Required

9.1 *Transverse or Longitudinal Tension Test* — One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes.

NOTE 3 — The term "lot," for mechanical tests, applies to all pipe of the same diameter and wall thickness (or schedule) which are produced from the same heat of steel and subjected to the same finishing treatment: (*1*) in a continuous heat-treatment furnace, or (*2*) in a batch-type heat-treatment furnace, equipped with recording pyrometers and automatically controlled within a 50°F [30°C] range, the larger of: (*a*) Each 200 ft [60 m] or fraction thereof or, (*b*) That pipe heat treated in the same batch furnace charge.

9.2 *Flattening Test* — For material heat treated in a batch-type furnace, flattening tests shall be made on 5% of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall be made on a sufficient number of pipe to constitute 5% of the lot, but in no case less than two lengths of pipe.

9.2.1 For welded pipe a transverse-guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5% of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

9.3 *Hydrostatic Test* — Each length of finished pipe shall be subjected to the hydrostatic test in accordance with Specification A 530/A 530M, unless specifically exempted under the provisions of 9.4 and 9.5.

9.4 For pipe whose dimensions equal or exceed NPS 10, the purchaser with the agreement of the manufacturer may waive the hydrostatic test requirement when in lieu of such test the purchaser performs a system test. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory markings the letters "NH."

9.5 *Nondestructive Examination:*

9.5.1 As an alternative to the hydrostatic test, and when specified by the purchaser, each pipe shall be examined with a nondestructive test in accordance with Practice E 213, or E 426. Unless specifically called out by the purchaser, the selection of the nondestructive electric test will be at the option of the manufacturer. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

9.5.2 The following information is for the benefit of the user of this specification.

9.5.2.1 The reference standards defined in 9.5.2.2 through 9.5.2.5 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

9.5.2.2 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep defects.

9.5.2.3 The eddy-current testing (ET) referenced in this specification, (Practice E 426), has the capability of detecting significant discontinuities, especially the short abrupt type.

9.5.2.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

9.5.3 *Time of Examination:*

9.5.3.1 Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

9.5.4 *Surface Condition:*

9.5.4.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

9.5.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

9.5.5 *Extent of Examination:*

9.5.5.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as in 9.5.5.2.

9.5.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

9.5.6 *Operator Qualifications:*

9.5.6.1 The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

9.5.7 *Test Conditions:*

9.5.7.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise-ratio.

9.5.7.2 The maximum eddy-current coil frequency used shall be as follows:

On specified walls up to 0.050 in.-100 KHz max
On specified walls up to 0.150 in.-50 KHz max
On specified walls up to 0.150 in.-10 KHz max

9.5.7.3 *Ultrasonic*-For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.00 MHz and the maximum nominal transducer size shall be 1.5 in.

(a) If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at that setting.

9.5.8 *Reference Standards:*

9.5.8.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish and heat treatment condition as the pipe to be examined.

9.5.8.2 *For Ultrasonic Testing*, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of each notch shall not exceed 12 $\frac{1}{2}$% of the specified nominal wall thickness of the pipe or 0.004 in., whichever is greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

9.5.8.3 *For Eddy-Current Testing*, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

(a) Drilled Hole — The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while

drilling. one hole shall be drilled in the weld, if visible. Alternately, the producer of welded pipe may choose to drill one hole in the weld and run the calibration standard through the test coils three times with the weld turned at 120 deg. on each pass. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
½	0.039 in. (1 mm)
above ½ to 1-¼	0.055 in. (1.4 mm)
above 1-¼ to 2	0.071 in. (1.8 mm)
above 2 to 5	0.087 in. (2.2 mm)
above 5	0.106 in. (2.7 mm)

(b) Transverse Tangential Notch-Using a round tool or file with a ¼ in. (6.4 mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12-½% of the specified nominal wall thickness of the pipe or 0.004 in. [0.102 mm], whichever is greater.

(c) Longitudinal Notch-A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12-½% of the specified wall thickness of the pipe or 0.004 in., whichever is greater. The length of the notch shall be compatible with the testing method.

9.5.8.4 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

9.5.9 *Standardization Procedure:*

9.5.9.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), Grade and heat treatment condition, and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

9.5.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, process shutdown or when a problem is suspected.

9.5.9.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

9.5.9.4 The signal-to-noise ratio for the reference standard shall be 2-½ to 1 or greater. Extraneous signals caused by identifiable causes such as dings, scratches, dents, straightener marks, etc., shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50% of full scale of the readout display.

9.5.9.5 If upon any standardization, the rejection amplitude has decreased by 29% (3 dB) of peak height from the last standardization, the pipe since the last calibration shall be rejected. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization must be retested for acceptance.

9.5.10 *Evaluation of Imperfections:*

9.5.10.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference standard(s) shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

9.5.10.2 Such pipes shall be rejected if the test signal was produced by imperfections that cannot be identified or was produced by crack or crack-like imperfections. These pipes may be repaired per Sections 11 and 12. To be accepted, a repaired pipe must pass the same non-destructive test by which it was rejected, and it must meet the minimum wall thickness requirements of this specification.

9.5.10.3 If the test signals were produced by visual imperfections such as:

(a) Scratches;
(b) Surface roughness;
(c) Dings;
(d) Straightener marks;
(e) Cutting chips;
(f) Steel die stamps;
(g) Stop marks, or;
(h) Pipe reducer ripple.

The pipe may be accepted based on visual examination provided the imperfection is less than 0.004 in. [0.1 mm] or 12-½% of the specified wall thickness (whichever is greater).

9.5.10.4 Rejected pipe may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

9.5.10.5 If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test providing

the imperfection does not encroach on the minimum wall thickness.

9.6 *Grain Size* — Grain size determinations on grades TP309H, TP309HCb, TP310H, TP310HCb, and UNS S32615 shall be made on the same number of tubes as prescribed for the flattening test.

10. Lengths

10.1 Pipe lengths shall be in accordance with the following regular practice:

10.1.1 Unless otherwise agreed upon, all sizes from NPS $\frac{1}{8}$ to and including NPS 8 are available in a length up to 24 ft [Note 4] with the permissible range of 15 to 24 ft [Note 4]. Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

NOTE 4 — This value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and the purchaser.

10.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and not more than $\frac{1}{4}$ in. [6 mm] over that specified.

10.1.3 No jointers are permitted unless otherwise specified.

11. Workmanship, Finish, and Appearance

11.1 The finished pipes shall be reasonably straight and shall have a workmanlike finish. Imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted in Section 8 of Specification A 530/A 530M.

12. Repair by Welding

12.1 For welded pipe whose diameter equals or exceeds NPS 6, and whose nominal wall thickness equals or exceeds 0.200, weld repairs made with the addition of compatible filler metal may be made to the weld seam with the same procedures specified for plate defects in the section on Repair by Welding of Specification A 530/A 530M.

12.2 Weld repairs of the weld seam shall not exceed 20% of the seam length.

12.3 Weld repairs shall be made only with the gas tungsten-arc welding process using the same classification of bare filler rod qualified to the most current AWS Specification A5.9 as the grade of stainless steel pipe being repaired and as shown in Table 4.

12.4 Pipes that have had weld seam repairs with filler metal shall be uniquely identified and shall be so stated and identified on the certificate of tests.

13. Certification

13.1 In addition to the information required by Specification A 530/A 530M, the certification shall state whether or not the material was hydrostatically tested. If the material was nondestructively tested, the certification shall so state and shall show which standard practice was followed and what reference discontinuities were used.

14. Marking

14.1 In addition to the marking specified in Specification A 530/A 530M, the marking shall include the NPS (nominal pipe size) and schedule, heat numbering and NH when hydrotesting is not performed and ET when eddy-current testing is performed or UT when ultrasonic testing is performed. The marking shall also include the manufacturer's private identifying mark, the marking requirement of 9.4, if applicable, and whether seamless or welded. For Grades TP304H, TP316H, TP321H, TP347H, TP348H, and S30815, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

15. Government Procurement

15.1 *Scale Free Pipe for Government Procurement:*

15.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry, contract or order, for agencies of the U.S. Government where scale free pipe or tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specifications.

15.1.2 The requirements of Specification A 530/A 530M for pipe and Specification A 450/A 450M for tubes shall be applicable when pipe or tube is ordered to this specification.

15.1.3 Pipe and tube shall be one of the following grades as specified herein:

Grade	UNS Designation
TP304	S30400
TP304L	S30403
TP304N	S31451
TP316	S31600
TP316L	S31603
TP316N	S31651
TP317	S31700
TP317L	S31703
TP321	S32100
TP347	S34700

15.1.4 *Part Number:*

Example: ASTM A 312/A 312M Pipe 304 NPS 12 SCH 40S SMLS

Specification Number	ASTM A 312
Pipe	P
Grade	304
NPS	12
Wall	0.375
SMLS OR WELDED	SML

15.1.4.1

Specification Number	ASTM A 312
Tube	T
Grade	304
Outside Diameter	0.250
Wall	0.035
SMLS OR WELDED	WLD

15.1.5 *Ordering Information* — Orders for material under this specification shall include the following in addition to the requirements of Section 3:

15.1.5.1 Pipe or tube,

15.1.5.2 Part number,

15.1.5.3 Ultrasonic inspection, if required,

15.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions,

15.1.5.5 Intergranular corrosion test, and

15.1.5.6 Level of preservation and packing required.

16. Keywords

16.1 austenitic stainless steel; seamless steel pipe; stainless steel pipe; steel pipe; welded steel pipe.

TABLE 1
CHEMICAL REQUIREMENTS

Grade	UNS Designation [Note (1)]	Composition, %																
		Carbon, max [Note (2)]	Manganese max [Note (2)]	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium plus Tantalum	Tantalum, max	Nitrogen [Note (3)]	Vanadium	Copper	Cerium	Boron	Aluminum
TP304	S30400	0.08	2.00	0.040	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	...	...	...	...		
TP304H	S30409	0.04–0.10	2.00	0.040	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	...	...	...	...		
TP304L	S30403	0.035 [Note (5)]	2.00	0.040	0.030	0.75 max	8.00–13.0	18.0–20.0	...	...	...	...	...	...	...	...		
TP304N	S30451	0.08	2.00	0.040	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...	...	...		
TP304LN	S30453	0.035	2.00	0.040	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...	...	...		
TP309Cb	S30940	0.08	2.00	0.045	0.030	0.75 max	12.0–16.0	22.0–24.0	0.75 max	...	10 × C min, 1.10 max	...	...	...		...		
TP309H	S30909	0.04–0.10	2.00	0.040	0.030	0.75 max	12.0–15.0	22.0–24.0	...	...	...	...	...	...	...			
TP309HCb	S30941	0.04–0.10	2.00	0.045	0.030	0.75 max	12.0–16.0	22.0–24.0	0.75 max	...	10 × C min, 1.10 max	...	...	...				
TP309S	S30908	0.08	2.00	0.045	0.030	0.75 max	12.0–15.0	22.0–24.0	0.75 max	...	...	...	...	...		...		
TP310Cb	S31040	0.08	2.00	0.045	0.030	0.75 max	19.0–22.0	24.0–26.0	0.75 max	...	10 × C min, 1.10 max	...	...	...		...		
TP310H	S31009	0.04–0.10	2.00	0.040	0.030	0.75 max	19.0–22.0	24.0–26.0	...	...	...	...	...	...	...			
TP310HCb	S31041	0.04–0.10	2.00	0.045	0.030	0.75 max	19.0–22.0	24.0–26.0	0.75 max	...	10 × C min, 1.10 max	...	...	...				
TP310S	S31008	0.08	2.00	0.045	0.030	0.75 max	19.0–22.0	24.0–26.0	0.75 max	...	...	...	...	...		...		
	S31272	0.08–012	1.5–2.00	0.030	0.015	0.3–0.7	14.0–16.0	14.0–16.0	1.0–1.4	0.3–0.6							0.004–0.008	
TP316	S31600	0.08	2.00	0.040	0.030	0.75 max	11.0–14.0 [Note (4)]	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...		
TP316H	S31609	0.04–0.10	2.00	0.040	0.030	0.75 max	11.0–14.0 [Note (4)]	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...		
TP316L	S31603	0.035 [Note (5)]	2.00	0.040	0.030	0.75 max	10.0–15.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...		
TP316N	S31651	0.08	2.00	0.040	0.030	0.75 max	11.0–14.0 [Note (4)]	16.0–18.0	2.00–3.00				0.10–0.16	...	...	...		
TP316LN	S31653	0.035	2.00	0.040	0.030	0.75 max	11.0–14.0 [Note (4)]	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...	...	...		
TP317	S31700	0.08	2.00	0.040	0.030	0.75 max	11.0–14.0	18.0–20.0	3.00–4.00	...	...	...	...	...	...	...		
TP317L	S31703	0.035	2.00	0.040	0.030	0.75 max	11.0–15.0	18.0–20.0	3.00–4.00	...	...	...	...	...	...	...		
TP321	S32100	0.08	2.00	0.040	0.030	0.75 max	9.00–13.0	17.0–20.0	...	[Note (6)]	...	...	...	...	...	...		
TP321H	S32109	0.04–0.10	2.00	0.040	0.030	0.75 max	9.00–13.0	17.0–20.0	...	[Note (7)]	...	...	...	...	...	...		
TP347	S34700	0.08	2.00	0.040	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[Note (8)]	...	...	...	...	...		
TP347H	S34709	0.04–0.10	2.00	0.040	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[Note (9)]	...	...	...	...	...		
TP347LN	S34751	0.005–0.020	2.00	0.040	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	0.2–0.5 [Note (11)]	...	0.06–0.10	...	...	...	...	...
TP348	S34800	0.08	2.00	0.040	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[Note (8)]	0.10	...	...	...	...		
TP348H	S34809	0.04–0.10	2.00	0.040	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[Note (9)]	0.10	...	...	...	...		

TABLE 1
CHEMICAL REQUIREMENTS (CONT'D)

Grade	UNS Designation [Note (1)]	Composition, %																
		Carbon, max [Note (2)]	Manganese max [Note (2)]	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium plus Tantalum	Tantalum, max	Nitrogen [Note (3)]	Vanadium	Copper	Cerium	Boron	Aluminum
TPXM-10	S21900	0.08	8.00–10.00	0.040	0.030	1.00 max	5.50–7.50	19.0–21.5	...	...	...	...	0.15–0.40	...	...	...		
TPXM-11	S21904	0.04	8.00–10.00	0.040	0.030	1.00 max	5.50–7.50	19.0–21.5	...	...	...	...	0.15–0.40	...	...	...		
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.5–18.5	17.0–19.0	...	...	...	...	...	...	...	...		
TPXM-19	S20910	0.060	4.00–6.00	0.040	0.030	1.00 max	11.5–13.5	20.5–23.5	1.50–3.00	...	0.10–0.30	...	0.20–0.40	0.10–0.30	...	...		
TPXM-29	S24000	0.080	11.5–14.5	0.060	0.030	1.00 max	2.25–3.75	17.0–19.0	...	...	...	...	0.20–0.40	...	...	...		
...	S31254	0.020	1.00	0.030	0.010	0.80 max	17.5–18.5	19.5–20.5	6.00–6.50	...	...	...	0.18–0.22	...	0.50–1.00	...		
...	S30615	0.16–0.24	2.00	0.03	0.03	3.2–4.0	13.5–16.0	17.0–19.5	...	...	...	...	...	...	...	...	...	0.8–1.5
...	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	...	...	...	...	0.14–0.20	...	...	0.03–0.08	...	
...	S31050	0.25	2.00	0.020	0.015	0.4	20.5–23.5	24.0–26.0	1.6–2.6	...	...	...	0.09–0.15	...	...	...		
...	S30600	0.018	2.00	0.02	0.02	3.7–4.3	14.0–15.5	17.0–18.5	0.20 max	...	...	...	...	...	0.50 max	...		
...	S31725	0.03	2.00	0.040 [Note (10)]	0.030	0.75	13.5–17.5	18.0–20.0	4.0–5.0	...	...	...	0.10 max	...	0.75 max	...		
...	S31726	0.03	2.00	0.040 [Note (10)]	0.030	0.75	13.5–17.5	17.0–20.0	4.0–5.0	...	...	...	0.10–0.20	...	0.75 max	...		
...	S32615	0.07	2.00	0.045	0.030	4.8–6.0	19.0–22.0	16.5–19.5	0.3–1.5	...	...	...	...	...	1.5–2.5	...		
...	S33228	0.04–0.08	1.0	0.020	0.015	0.30 max	31.0–33.0	26.0–28.0	...	...	0.6–1.0	...	...	...	...	0.05–0.10	...	0.025 max
...	S24565	0.03	5.0–7.0	0.030	0.010	1.00 max	16.0–18.0	23.0–25.0	4.0–5.0	...	0.1 max		0.4–0.6	...	...	...	...	
...	S30415	0.04–0.06	0.80	0.045	0.030	1.00–2.00	9.00–10.0	18.0–19.0	...	...	...	...	0.12–0.18	...	...	0.03–0.08	...	
...	S32654	0.020	2.00–4.00	0.030	0.005	0.50 max	21.0–23.0	24.0–25.0	7.00–8.00	...	...	...	0.45–0.55	...	0.30–0.60	...		
...	S35315	0.04–0.08	2.00	0.045	0.030	0.75	34.0–36.0	24.0–26.0	...	...	...	...	0.12–0.18	...	...	0.03–0.08	...	...
...	N08367	0.030	2.00	0.040	0.030	1.00 max	23.50–25.50	20.00–22.00	6.00–7.00	...	...	...	0.18–0.25	...	0.75 max	...	...	...
...	N08904	0.020	2.00	0.045	0.035	1.00	23.0–28.0	19.0–23.0	4.0–5.0	...	...	...	0.10 max	...	1.0–2.0	...	...	...

NOTES:
(1) New designation established in accordance with Practice E 527 and SAE J1086.
(2) Maximum, unless otherwise indicated.
(3) The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
(4) For welded TP316, TP316N, TP316LN, and TP316H pipe, the nickel range shall be 10.0–14.0%.
(5) For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040% is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.20 mm] in average wall thickness [0.044 in. [1.10 mm] in minimum wall thickness].
(6) The titanium content shall be not less than five times the carbon content and not more than 0.70%.
(7) The titanium content shall be not less than four times the carbon content and not more than 0.60%.
(8) The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.00%.
(9) The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.0%.
(10) For welded pipe, the phosphorus maximum shall be 0.045%.
(11) Grade S34751 shall have a columbium (niobium) plus tantalum content of not less than 15 times the carbon content.

TABLE 2
ANNEALING REQUIREMENTS

Grade or UNS Designation [A]	Solution Treating Temperature [B]	Cooling Requirements
All grades not individually listed below:	1900°F [1040°C]	rapid[C]
TP321H, TP347H, TP348H		
Cold Rolled	2000°F [1100°C]	
Hot Rolled Only	1925°F [1050°C]	
TP304H, TP316H		
Cold Rolled	1900°F [1040°C]	
Hot Rolled Only	1900°F [1040°C]	
TP309H, TP309HCb, TP310H, TP310HCb	1900°F [1040°C]	
S30815	1920°F [1050°C]	rapid
S31272	1920°F [1050°C]	rapid
S31254	2100°F [1150°C]	rapid
S24565	2050–2140°F [1120–1170°C]	rapid
S35315	2010°F [1100°C]	rapid
N08367	2025°F [1110°C]	rapid
N08904	2000°F [1040°C]	rapid

[A] New designation established in accordance with Practice E 527 and SAE J1086.
[B] Minimum, unless otherwise stated.
[C] Rapid: Pipe shall be water quenched or rapidly cooled by other means.

TABLE 3
TENSILE REQUIREMENTS

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
TP304L	S30403	70 [485]	25 [170]
TP316L	S31603	70 [485]	25 [170]
TP304	S30400	75 [515]	30 [205]
TP304H	S30409	75 [515]	30 [205]
TP309Cb	S30940	75 [515]	30 [205]
TP309H	S30909	75 [515]	30 [205]
TP309HCb	S30941	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310H	S31009	75 [515]	30 [205]
TP310HCb	S31041	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
	S31272	65 [450]	29 [200]
TP316	S31600	75 [515]	30 [205]
TP316H	S31609	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
TP321	S32100:		
Welded		75 [515]	30 [205]
Seamless:			
≤ 3/8 in.		75 [515]	30 [205]
> 3/8 in.		70 [485]	25 [170]
TP321H	S32109:		
Welded		75 [515]	30 [205]
Seamless:			
≤ 3/8 in.		75 [515]	30 [205]
> 3/8 in. [Note (1)]		70 [485]	25 [170]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21904	90 [620]	50 [345]
TPXM-15	S38100	75 [515]	30 [205]
TPXM-29	S24000	100 [690]	55 [380]
TPXM-19	S20910	100 [690]	55 [380]
TP304N	S30451	80 [550]	35 [240]
TP316N	S31651	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
TP316LN	S31653	75 [515]	30 [205]
...	S31254	94 [650]	44 [300]
...	S30615	90 [620]	40 [275]
...	S30815	87 [600]	45 [310]
...	S30600	78 [540]	35 [240]
...	S31725	75 [515]	30 [205]
...	S31726	80 [550]	35 [240]
...	S31050:		
t ≤ 0.25 in.		84 [580]	39 [270]
t > 0.25 in.		78 [540]	37 [255]
...	S32615	80 [550]	32 [220]
...	S33228	73 [500]	27 [185]
...	S24565	115 [795]	60 [415]
...	S30415	87 [600]	42 [290]
...	S32654	109 [750]	62 [430]
...	S35315	94 [650]	39 [270]
...	N08367;		
t ≤ 0.187		100 [690]	45 [310]
t > 0.187		95 [655]	45 [310]
...	N08904	71 [490]	31 [215]

TABLE 3 (CONT'D)
TENSILE REQUIREMENTS

Elongation in 2 in. or 50 mm (or 4*D*), min, %:	Longitudinal	Transverse
All Grades except S31050 and S32615	35	25
S32615, S31050	25	...
N08367	30	...

NOTE:
(1) Prior to the issuance of A 312/A 312M–88a, the tensile and yield strength values were 76 [515] and 30 [205], respectively, for nominal wall greater than 3/8 in. [9.5 mm].

TABLE 4
PIPE AND FILLER METAL SPECIFICATION

Pipe		Filler Metal	
Grade	UNS Designation	AWS A5.9 Class	UNS Designation
TP304	S30400	ER308	S30800, W30840
TP304L	S30403	ER308L	S30883, W30843
TP304N	S30451	ER308	S30880, W30840
TP304LN	S30453	ER308L	S30883, W30843
TP304H	S30409	ER308	S30880, W30840
TP309Cb	S30940	...	... ...
TP309S	S30908	...	... ...
TP310Cb	S31040	...	... ...
TP310S	S31008	...	... ...
	S31272	...	... ...
TP316	S31600	ER316	S31680, W31640
TP316L	S31603	ER316L	S31683, W31643
TP316N	S31651	ER316	S31680, W31640
TP316LN	S31653	ER316L	S31683, W31643
TP316H	S31609	ER316H	S31680, W31640
TP321	S32100	ER321	S32180, W32140
		ER347	S34780, W34740
TP347	S34700	ER347	S34780, W34740
TP348	S34800	ER347	S34780, W34740
TPXM-19	S22100	ER209	S20980, W32240
TPXM-29	S28300	ER240	S23980, W32440
...	N08367	...	N06625

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe NPS 5 and larger in nominal size there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10% of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 6 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10% of the lengths furnished per heat of steel. This applies only to pipe NPS 8 and larger.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Radiographic Examination

S5.1 The entire length of weld in each double welded pipe shall be radiographically examined, using X-radiation, in accordance with Paragraph UW-51 of Section VIII Division 1 of the ASME Boiler and Pressure Vessel Code. In addition to the marking required by Section 13 each pipe shall be marked “RT” after the specification and grade. Requirements of S5 shall be required in the certification.

S6. Stabilizing Heat Treatment

S6.1 Subsequent to the solution anneal required in 5.3, Grades TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S7. Intergranular Corrosion Test

S7.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE 5 — Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S7.2 A stabilization heat treatment in accordance with Supplementary Requirement S6 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

S8. Minimum Wall Pipe

S8.1 When specified by the purchaser, pipe shall be furnished on a minimum wall basis. The wall of such pipe shall not fall below the thickness specified. In addition to the marking required by Section 13, the pipe shall be marked S8.

APPENDIX

(Nonmandatory Information)

X1. TABLE X1.1 IS BASED ON TABLE 1 OF THE AMERICAN NATIONAL STANDARD FOR STAINLESS STEEL PIPE (ANSI B36.19-1965)

TABLE X1.1
DIMENSIONS OF WELDED AND SEAMLESS STAINLESS STEEL PIPE

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S [Note (1)]		Schedule 10S [Note (1)]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
1/8	0.405	10.29	...	...	0.049	1.24	0.068	1.73	0.095	2.41
1/4	0.540	13.72	...	...	0.065	1.65	0.088	2.24	0.119	3.02
3/8	0.675	17.15	...	...	0.065	1.65	0.091	2.31	0.126	3.20
1/2	0.840	21.34	0.065	1.65	0.083	2.11	0.109	2.77	0.147	3.73
3/4	1.050	26.67	0.065	1.65	0.083	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065	1.65	0.109	2.77	0.133	3.38	0.179	4.55
1 1/4	1.660	42.16	0.065	1.65	0.109	2.77	0.140	3.56	0.191	4.85
1 1/2	1.900	48.26	0.065	1.65	0.109	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
2 1/2	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62
3 1/2	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134	3.40	0.165	4.19	0.365	9.27	0.500 [Note (2)]	12.70 [Note (2)]
12	12.750	323.85	0.156	3.96	0.180	4.57	0.375 [Note (2)]	9.52 [Note (2)]	0.500 [Note (2)]	12.70 [Note (2)]
14	14.000	355.60	0.156	3.96	0.188 [Note (2)]	4.78 [Note (2)]	...	...	...	...
16	16.000	406.40	0.165	4.19	0.188 [Note (2)]	4.78 [Note (2)]	...	...	...	...
18	18.000	457.20	0.165	4.19	0.188 [Note (2)]	4.78 [Note (2)]	...	...	...	...
20	20.000	508.00	0.188	4.78	0.218 [Note (2)]	5.54 [Note (2)]	...	...	...	...
22	22.000	558.80	0.188	4.78	0.218 [Note (2)]	5.54 [Note (2)]	...	...	...	...
24	24.000	609.60	0.218	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

GENERAL NOTE—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.
NOTES:
(1) Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).
(2) These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10–1979).

SPECIFICATION FOR ALLOY STEEL BOLTING MATERIALS FOR LOW-TEMPERATURE SERVICE

SA-320/SA-320M

(Identical with ASTM Specification A 320/A 320M-94a (Reapproved 1995)[E1].)

1. Scope

1.1 This specification covers alloy steel bolting materials for pressure vessels, valves, flanges, and fittings for low-temperature service. The term "bolting material" as used in this specification covers rolled, forged, or strain hardened bars, bolts, screws, studs, and stud bolts. The bars shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be solution annealed or annealed and strain-hardened.

1.2 Several grades are covered, including both ferritic and austenitic steels designated L7, B8 etc. Selection will depend on design, service conditions, mechanical properties, and low-temperature characteristics. The mechanical requirements of Table 1 indicate the diameters for which the minimum mechanical properties apply to the various grades and classes, and Table 2 stipulates the requirements for Charpy impact energy absorption. The manufacturer should determine that the material can conform to these requirements before parts are manufactured. For example, when Grade L43 is specified to meet the Table 2 impact energy values at −150°F [−101°C], additional restrictions (such as procuring a steel with lower P and S contents than might normally be supplied) in the chemical composition for AISI 4340 are likely to be required.

NOTE 1—The committee formulating this specification has included several grades of material that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent. Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtainable.

1.3 Nuts for use with this bolting material are covered in Section 9 and the nut material shall be impact tested.

1.4 Supplementary Requirements (S1, S2 and S3) of an optional nature are provided. They shall apply only when specified in the inquiry, contract and order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for

A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service

A 276 Specification for Stainless and Heat-Resisting Steel Bars and Shapes

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
F 436 Specification for Hardened Steel Washers

2.2 *American National Standards Institute Standards:*
B18.2.1 Square and Hex Bolts and Screws
B18.3 Hexagon Socket and Spline Socket Screws
B18.22.1 Plain Washers

2.3 *AIAG Standard:*
AIAG B-5 0200 Primary Metals Identification Tag Application Standard

3. Ordering Information

3.1 The inquiry and order for material under this specification shall include the following as required to describe the material adequately:

3.1.1 Specification designation latest issue, and analysis by grade as selected from Table 3,

3.1.2 Heat-treated condition (that is, for the austenitic stainless steels, solution treated (Class 1); solution treated after finishing (Class 1A), and annealed- and strain-hardened (Class 2)),

3.1.3 Quantity (number of pieces or weight),

3.1.4 Description of items required (bars, bolts, screws, or studs),

3.1.5 Dimensions (diameter, length of point, overall length, finish, shape, and threads),

3.1.6 Nuts and washers, if required by purchaser, in accordance with Section 9.

3.1.7 End use,

3.1.8 Supplementary requirements, if any, and

3.1.9 Special requirements, in accordance with 4.3.1, 4.3.2, 4.3.3, 7.3, 10.1, 11.1, and 14.1.

4. Materials and Manufacture

4.1 *Process*—The steel shall be produced by any of the following primary processes: open-hearth, basic-oxygen, electric-furnace, or vacuum-induction melting (VIM). The primary melting may incorporate separate degassing or refining. The molten steel may be vacuum-treated prior to or during pouring of the ingot. The basic oxygen process shall be limited to steels containing not over 6% chromium.

4.2 *Discard*—A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

4.3 *Heat Treatment:*

4.3.1 The bolting material shall be allowed to cool to room temperature after rolling or forging. Grades L7, L7A, L7B, L7C, L7M, L43, L1, L70, L71, L72, and L73 shall be reheated to above the upper critical temperature and liquid quenched and tempered. Grades B8, B8C, B8M, B8T, B8F, B8P, B8LN, and B8MLN shall receive a carbide solution treatment. Products made from such material are described as Class 1. This shall consist of holding the material for a sufficient time at a temperature at which the chromium carbide will go into solution and then cooling in air or in a liquid medium at a rate sufficient to prevent reprecipitation of the carbide. Material thus treated is described as Class 1. If specified in the purchase order, material shall be solution treated in the finished condition; material so treated is described as Class 1A.

4.3.2 When increased mechanical properties are desired, the austenitic bolting materials shall be solution annealed and strain hardened if specified in the purchase order; material so treated is identified as Class 2.

4.3.3 If scale-free bright finish is required, this shall be specified in the purchase order.

4.3.4 For L7M bolting, the final heat treatment, which may be the tempering or stress-relieving operation conducted at 1150°F [620°C] minimum, shall be done after machining or rolling of the threads.

5. Chemical Composition

5.1 *Heat Analysis*—An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Table 3. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements prescribed in Table 3.

5.2 *Product Analysis*—An analysis may be made by the purchaser from samples representing the bolting material. The chemical composition thus determined shall conform to the requirements prescribed in Table 3.

5.3 The steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element. Furthermore, elements present in concentrations greater than 0.75 weight/percent shall be reported. Chemical analysis shall be performed in accordance with Test Methods A 751.

6. Mechanical Requirements

6.1 *Tensile Properties:*

6.1.1 The material shall conform to the requirements as to tensile properties prescribed in Table 1 at room temperature after heat treatment (see 4.3.1).

6.1.2 *Number of Tests:*

6.1.2.1 For heat-treated bars, one tension test and one impact test consisting of three specimens shall be made for each diameter of each heat represented in each tempering charge. In the continuous type treatment, a charge shall be defined as 6000 lb [2700 kg].

6.1.2.2 For studs, bolts, screws, etc., one tension test and one set of three impact specimens shall be made for each diameter of each heat involved in the lot. Each lot shall consist of the following:

Diameter, in. [mm]	Lot Size, lb [kg]
1⅛ [30] and under	1500 [680] or fraction thereof
Over 1⅛ [30] to 1¾ [45], incl	4500 [2040] or fraction thereof
Over 1¾ [45] to 2½ [65], incl	6000 [2700] or fraction thereof
Over 2½ [65]	100 pieces or fraction thereof

6.1.2.3 Tension and impact tests are not required to be made on bolts, screws, studs, or stud bolts which are fabricated from heat-treated bars furnished in accordance with the requirements of this specification and tested in accordance with 6.1.2.1, provided they are not given a subsequent heat treatment.

6.1.3 *Test Specimens*—Tension test specimens taken from finished bolts, screws, studs, or stud bolts shall be machined to the form and dimensions and shall be taken from positions shown in Annex A3 on Steel Fasteners, paragraph A3.2.1.7 of Test Methods and Definitions A 370. Tension test specimens from bar stock are covered by Test Methods and Definitions A 370 in Annex A1, "Steel Bar Products."

6.1.4 *Test Method*—Tension tests shall be made in accordance with Test Methods and Definitions A 370 including speed of testing in the section on Testing Apparatus and Operations, on speed of testing, and the parts of Annex A3, "Steel Fasteners," applicable to machined tests specimens.

6.2 *Impact Properties:*

6.2.1 *Requirements:*

6.2.1.1 Material of Grades L7, L7A, L7B, L7C, L7M, L43, L70, L71, L72, and L73 shall show a minimum impact energy absorption of 20 ft · lbf [27 J] and of Grade L1 a minimum impact energy absorption of 40 ft · lbf [54 J] at the test temperature when tested by the procedure specified in the applicable portions of Sections 19 to 23 of Test Methods and Definitions A 370. The temperature of the coolant used for chilling the test specimens shall be controlled within ±3°F [1.5°C]. Impact tests are not required for carbide solution treated or strain hardened Grades B8, B8F, B8P, B8M, B8T, B8LN and B8MLN for temperatures above −325°F [−200°C]; for carbide solution treated Grades B8, B8P, B8C, and B8LN above −425°F [−255°C]; for all ferritic and austenitic steel grades of bolting ½ in. [12.5 mm] and smaller in diameter. All other material furnished under this specification shall be tested. Test temperatures for ferritic grades are listed in Table 4. Exceptions to this requirement are permissible, and the impact tests may be made at specified temperatures different than those shown in Table 4, provided the test temperature is at least as low as the intended service temperature and the bolting is suitably marked to identify the reported test temperature. When impact testing is required for austenitic grades, test criteria shall be agreed upon between the supplier and purchaser.

6.2.1.2 The impact test requirements for standard and subsize Charpy test specimens are prescribed in Table 2.

6.2.2 *Number of Tests:*

6.2.2.1 The test requirements for heat-treated bars are given in 6.1.2.1.

6.2.2.2 For test requirements on studs, bolts, screws, etc., see 6.1.2.2 and 6.1.2.3.

6.2.2.3 Impact tests are not required to be made on heat-treated bars, bolts, screws, studs, and stud bolts ½ in. [12.5 mm] and under in diameter.

6.2.3 *Test Specimens:*

6.2.3.1 The impact test specimen shall have the form and dimensions shown in Fig. 10 of Test Methods and Definitions A 370 for the Charpy V-notch specimen, Type A. The notch shall be located on the test specimen surface which most closely approaches a radial direction.

The base of the notch shall be as nearly as practicable perpendicular to the surface of the bar.

6.2.3.2 For sections 1 in. [25 mm] or less in diameter, test specimens shall be taken at the axis; for sections over 1 in. [25 mm] in diameter, midway between the axis and the surface.

6.3 *Hardness Requirements:*

6.3.1 The hardness shall conform to the requirements prescribed in Table 1 with testing performed in accordance with Test Methods and Definitions A 370.

6.3.2 The maximum hardness of Grade L7M shall be 235 HB or 99 HRB (conversion in accordance with Table 2B of Test Methods and Definitions A 370). Minimum hardness shall not be less than 200 HB or 93 HRB. Conformance to this hardness shall be ensured by testing the hardness of each stud or bolt by Brinell or Rockwell B methods as described in the sections on Brinell Test, Portable Hardness Test, and Rockwell Test of Test Methods and Definitions A 370.

6.3.2.1 The use of 100% electromagnetic testing for hardness as an alternative to 100% indentation hardness testing is permissible when qualified by sampling using indentation hardness testing. Each lot tested for hardness electromagnetically shall be 100% examined in accordance with Practice E 566. Following electromagnetic testing for hardness, a random sample of a minimum of 100 pieces in each purchase lot (as defined in 6.1.2.2) shall be tested by indentation hardness methods. All samples must meet hardness requirements to permit acceptance of the lot. If any one sample is outside of the specified maximum or minimum hardness, the lot shall be rejected and either reprocessed and resampled, or tested 100% by indentation hardness methods.

6.3.2.2 In the event a controversy exists relative to minimum strength, tension tests shall prevail over hardness readings. Products which have been tested and found acceptable shall have a line under the grade symbol.

6.3.2.3 Surface preparation for indentation hardness testing shall be in accordance with Test Methods E 18. Hardness tests shall be performed on the end of the bolt or stud. When this is impractical, the hardness test shall be performed elsewhere.

7. Workmanship, Finish, and Appearance

7.1 Bolts, screws, studs, and stud bolts shall be pointed and shall have a workmanlike finish. Points shall be flat and chamfered or rounded at option of the manufacturer. Length of points on studs and stud bolts shall be not less than one nor more than two complete threads as measured from the extreme end parallel to the axis. Length of studs and stud bolts shall be measured from first thread to first thread.

7.2 Standard permissible variations for dimensions of bars shall be as prescribed in Table 5. Aside from the tolerances given in Table 5, additional tolerances for the basic materials are given in Specifications A 29/A 29M and A 276.

7.3 Bolt heads shall be in accordance with the dimensions of ANSI B18.2.1. Unless otherwise specified in the purchase order, the Heavy Hex Screws Series should be used, except the maximum body diameter and radius of fillet may be the same as for the Heavy Hex Bolt Series. Socket-head fasteners shall be in accordance with ANSI B18.3.

8. Retests

8.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension tests and one additional impact test consisting of three specimens shall be made from such lot, all of which shall conform to the requirements specified.

9. Nuts and Washers

9.1 Bolts, studs, and stud bolts of Grades L7, L7A, L7B, L7C, L43, L1, L70, L71, L72, and L73 shall be equipped with ferritic alloy nuts conforming to Grade 4 or Grade 7 of Specification A 194/A 194M or a grade of steel similar to the studs. Grade 7M nuts at a hardness not exceeding 235 HB (or equivalent) shall be used with Grade L7M bolts, studs, and stud bolts. All nut materials, including those which may be supplied under Specification A 194/A 194M, shall be subject to the impact requirements of this specification in the following manner: impact tests shall be made on test specimens taken from the bar or plate from the heat of steel used for manufacturing the nuts, and heat treated with the nut blanks.

9.2 Bolts, studs, and stud bolts of Grades B8, B8C, B8T, B8P, B8F, B8M, B8LN, and B8MLN shall be

equipped with austenitic alloy nuts conforming to Grades 8, 8C, 8T, 8F, 8M, 8LN, and 8MLN for Specification A 194/A 194M. Impact tests are not required for Grades 8F, 8M, 8T, and 8MLN for temperatures above −325°F [−200°C] and for Grades 8, 8P, 8C, and 8LN above −425°F [−255°C].

9.3 If the purchaser requires nuts with a Charpy impact energy absorption of not less than 20 ft · lbf [27 J] at temperatures below −150°F [−100°C], he may require that the nuts conform to Grades 8, 8C, 8M, 8P, 8T, 8F, 8LN, or 8MLN of Specification A 194/A 194M.

9.4 Washers for use with ferritic steel bolting shall conform to Specification F 436.

9.5 Washers for use with austenitic steel bolting shall be made of austenitic steel as agreed upon between the manufacturer and purchaser.

9.6 Washer dimensions shall be in accordance with requirements of ANSI B18.22.1, unless otherwise specified in the purchase order.

10. Threads

10.1 All alloy steel bolts, studs, and stud bolts, unless otherwise specified, shall be threaded in accordance with ANSI B1.1, Class 2A fit, sizes 1 in. [25 mm] and smaller in diameter with the Coarse Thread Series, and 1⅛ in. [29 mm] and larger in diameter with the 8 Pitch Thread Series.

10.2 Where practical, all threads shall be formed after heat treatment. Class 1A, Grades B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, and B8MLNA are to be solution-treated in the finished condition.

11. Inspection

11.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

12. Rejection and Rehearing

12.1 *Rejection:*

12.1.1 Unless otherwise specified in the order, any rejection based on tests made in accordance with 5.2 shall be reported to the manufacturer within 30 days from the receipt of samples by the purchaser.

12.1.2 Material that shows defects subsequent to its acceptance at the manufacturer's works shall be rejected, and the manufacturer shall be notified.

12.2 *Rehearing*—Samples tested in accordance with 5.2 that represent rejected material shall be preserved for 2 weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

13. Certification

13.1 When agreed upon in writing between the manufacturer and the purchaser, a certification that the material conforms to the requirements of this specification shall be the basis of acceptance of the material. Otherwise, the manufacturer shall report to the purchaser or the purchaser's representative the results of the chemical analyses and mechanical tests made in accordance with the specification. The specification designation included on test reports shall include year of issue and revision letter, if any.

14. Product Marking

14.1 Grade and manufacturer's symbols shall be applied to one end of studs ⅜ in. [10 mm] in diameter and larger and to the heads of bolts ¼ in. [6 mm] in diameter and larger. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) The identification symbol shall be as shown in Table 3. In the case of Class 2, Grades B8, B8C, B8M, B8P, B8F, and B8T strain hardened as provided in Table 1, a line shall be stamped under the grade symbol in order to distinguish it from Class 1 and Class 1A bolting which has not been strain hardened. In the case of Class 1A, the marking B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, and B8MLNA identifies the material as being in the solution-treated condition in the finished state. Grade L7M which has been 100% evaluated in conformance with this specification shall have a line under the grade symbol

to distinguish it from L7M produced to previous revisions not requiring 100% hardness testing.

14.2 For bolting materials, including threaded bars, that are furnished bundled and tagged or boxed, the tags and boxes shall carry the grade symbol for the material identification and the manufacturer's identification mark or name.

14.3 Nuts from materials that have been impact tested shall be marked with the letter "L."

14.4 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

14.5 *Bar Coding*—In addition to the requirements in 14.1, 14.2, 14.3, and 14.4, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard B-5 02.00. If used on small items, the bar code may be applied to the box or a substantially applied tag.

15. Keywords

15.1 additional elements; austenitic stainless steel; bolts—steel; chromium-molybdenum steel; fasteners—steel; markings on fittings; nickel-chromium-molybdenum alloy steel; pressure vessel service; stainless steel bolting material; starting material; steel bars—alloy; steel bolting material; steel flanges; steel valves; temperature service applications—low

TABLE 1
MECHANICAL REQUIREMENTS

Class and Grade, Diameter, in [mm]	Heat Treatment	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa] (0.2% offset)	Elongation in 2 in. or 50 mm min, %	Reduction of Area, min, %	Hardness max
Ferritic Steels						
L7, L7A, L7B, L7C, L70, L71, L72, L73		125	105	16	50	. . .
2½ [65] and under	quenched and tempered	[860]	[725]			
L43		125	105	16	50	. . .
4 [100] and under	quenched and tempered	[860]	[725]			
L7M		100	80	18	50	235 HB[B] or 99 HRB
2½ [65] and under	quenched and tempered at 1150°F [620°C], min	[690]	[550]			
L1		125	105	16	50	. . .
1[25] and under	quenched and tempered	[860]	[725]			
Austenitic Steels[A]						
Class 1: B8, B8C, B8M, B8P, B8F, B8T, B8LN, B8MLN, all diameters	carbide solution treated	75 [515]	30 [205]	35	50	223 HB[D] or 96 HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, B8MLNA, all diameters	carbide solution treated in the finished condition	75 [515]	30 [205]	35	50	192 HB or 90 HRB
Class 2: B8, B8C, B8F, B8T:	carbide solution treated and strain hardened					
¾ [20] and under		125 [860]	100 [690]	12	35	321 HB or 35 HRC
over ¾ to 1 [20 to 25], incl		115 [795]	80 [550]	15	30	321 HB or 35 HRC
over 1 to 1¼ [25 to 32], incl		105 [725]	65 [450]	20	35	321 HB or 35 HRC
over 1¼ to 1½ [32 to 40], incl		100 [690]	50 [345]	28	45	321 HB or 35 HRC
Class 2: B8M:	carbide solution treated and strain hardened					
¾ [20] and under		110 [760]	95 [655]	15	45	321 HB or 35 HRC
over ¾ to 1 [20 to 25], incl		100 [690]	80 [550]	20	45	321 HB or 35 HRC
over 1 to 1¼ [25 to 32], incl		95 [655]	65 [450]	25	45	321 HB or 35 HRC
over 1¼ to 1½ [32 to 40], incl		90 [620]	50 [345]	30	45	321 HB or 35 HRC

[A] These upper diameter limits were established on the basis that these were the largest sizes commonly available that consistently met specification property limits. They are not intended as absolute limits beyond which bolting materials could no longer be certified to the specification.

[B] To meet the tensile requirements, the Brinell hardness shall not be less than 200 HB or 93 HRB.

[C] Class 1 products are made from solution-treated material. Class 1A products are solution treated in the finished condition for corrosion resistance, heat treatment is critical for enhancing this physical property and meeting the mechanical property requirements. Class 2 products are made from solution-treated material that has been strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the cross section, particularly in sizes over ¾ in. [20 mm] in diameter.

[D] For sizes ¾ in. [20 mm] in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.

TABLE 2
IMPACT ENERGY ABSORPTION REQUIREMENTS

Size of Specimen, mm	Minimum Impact Value Require for Average of Each Set of Three Specimens, ft · lbf [J]	Minimum Impact Value Permitted for One Specimen Only of a Set, ft · lbf [J]
All Grades Except L1[A]		
10 by 10	20 [27]	15 [20]
10 by 7.5	16 [22]	12 [16]
Grade L1		
10 by 10	40 [54]	30 [41]
10 by 7.5	32 [44]	24 [32]

[A] See 6.2.1.1 for permitted exemptions.

TABLE 3
CHEMICAL REQUIREMENTS (COMPOSITION, %)[A]

Type	Ferritic Steels											
Identification Symbol	L7, L7M, L70		L7A, L71		L7B, L72		L7C, L73		L43		L1	
Grade	Chromium-Molybdenum (AISI 4140, 4142, or 4145)		Carbon-Molybdenum (AISI 4037)		Chromium-Molybdenum (AISI 4137)		Nickel-Chromium-Molybdenum (AISI 8740)		Nickel-Chromium-Molybdenum (AISI 4340)		Low-Carbon Boron	
	Range, %	Product Variation, % Over or Under[B]	Range, %	Product Variation, % Over or Under[B]	Range, %	Product Variation, % Over or Under[B]	Range, %	Product Variation, % Over or Under[B]	Range, %	Product Variation, % Over or Under[B]	Range, %	Product Variation, % Over or Under[B]
Carbon	0.38–0.48[C]	0.02	0.35–0.40	0.02	0.35–0.40	0.02	0.38–0.43	0.02	0.38–0.43	0.02	0.17–0.24	0.01
Manganese	0.75–1.00	0.04	0.70–0.90	0.03	0.70–0.90	0.03	0.75–1.00	0.04	0.60–0.85	0.03	0.70–1.40	0.04
Phosphorus, max	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over
Sulfur, max	0.040	0.005 over	0.040	0.005 over	0.040	0.005 over	0.040	0.005 over	0.040	0.005 over	0.050	0.005 over
Silicon	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02
Nickel	. . .	. . .	. . .	. . .	. . .	. . .	0.40–0.70	0.03	165–2.00	0.05	. . .	. . .
Chromium	0.80–1.10	0.05	. . .	. . .	0.80–1.10	0.05	0.40–0.60	0.03	0.70–0.90	0.03	. . .	. . .
Molybdenum	0.15–0.25	0.02	0.20–0.30	0.02	0.15–0.25	0.02	0.20–0.30	0.02	0.20–0.30	0.02	. . .	. . .
Boron	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.001–0.003	. . .

Type	Austenitic Steels, Classes 1, 1A, and 2[D]			
Identification Symbol	B8, B8A		B8C, B8CA	
Grade	Unstabilized 18 Chromium-8 Nickel (AISI Type 304)		Stabilized 18 Chromium-8 Nickel (AISI Type 347)	
	Range, %	Product Variation, % Over or Under[B]	Range, %	Product Variation, % Over or Under[B]
Carbon, max	0.08	0.01 over	0.08	0.01 over
Manganese, max	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over
Nickel	8.0–10.5	0.15	9.0–13.0	0.15
Chromium	18.0–20.0	0.20	17.0–19.0	0.20
Columbium + tantalum	. . .	. . .	10 × carbon content, min	0.05 under

TABLE 3 (CONT'D)
CHEMICAL REQUIREMENTS (COMPOSITION, %)[A]

Type	Austenitic Steels, Classes 1, 1A, and 2[D]									
Identification Symbol	B8T, B8TA		B8P, B8PA		B8F, B8FA				B8M, B8MA	
Grade	Stabilized 18 Chromium-8 Nickel (AISI Type 321)		Unstabilized 18 Chromium-8 Nickel (AISI Type 305 with restricted carbon)		With Added Sulfur (Type 303)		With Added Selenium (Type 303 Se)		18 Chromium-10 Nickel-2 Molybdenum (AISI Type 316)	
	Range, %	Product Variation, % Over or Under[B]	Range, %	Product Variation, % Over or Under[B]	Range, %	Product Variation, % Over or Under[B]	Range, %	Product Variation, % Over or Under[B]	Range, %	Product Variation, % Over or Under[B]
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.15	0.01 over	0.15	0.01 over	0.08	0.01 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.20	0.010 over	0.20	0.010 over	0.045	0.010 over
Sulfur	0.030, max	0.005 over	0.030, max	0.005 over	0.15, min	0.020	0.06, max	0.010 over	0.030, max	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05
Nickel	9.0–12.0	0.15	10.5–13.0	0.15	8.0–10.0	0.10	8.0–10.0	0.10	10.0–14.0	0.15
Chromium	17.0–19.0	0.20	17.0–19.0	0.20	17.0–19.0	0.20	17.0–19.0	0.20	16.0–18.0	0.20
Molybdenum	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	2.00–3.00	0.10
Selenium	. . .	. . .	. . .	. . .	. . .	. . .	0.15–0.35	0.03 under	. . .	. . .
Titanium	5 × carbon content, min	0.05 under	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

Type	Austenitic Steels, Classes 1, 1A, and 2[D]			
Identification Symbol	B8LN, B8LNA		B8MLN, B8MLNA	
Grade	Unstabilized 18 Chromium-8 Nickel with Nitrogen (AISI Type 304N with restricted carbon)		Unstabilized 18 Chromium-10 Nickel-2 Molybdenum with Nitrogen (AISI Type 316N with restricted carbon)	
	Range, %	Product Variation, % Over or Under[B]	Range, %	Product Variation, % Over or Under[B]
Carbon, max	0.030	0.005 over	0.030	0.005 over
Manganese, max	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over
Nickel	8.0–10.5	0.15	10.0–14.0	0.15
Chromium	18.0–20.0	0.20	16.0–18.0	0.20
Molybdenum	. . .	. . .	2.00–3.00	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01

[A] The intentional addition of Bi, Se, Te, and Pb is not permitted except for Grade B8F, in which selenium is specified and required.

[B] *Product analysis* — individual, determinations sometimes vary from the specified limits on ranges as shown in the tables. The several determinations of any individual element in a heat may not vary both above and below the specified range.

[C] For the L7M grade, a minimum carbon content of 0.28% is permitted provided that the required tensile properties are met in the section sizes involved; the use of AISI 4130 or 4130H is allowed.

[D] Class 1 are made from solution-treated material. Class 1A products (B8A, B8CA, B8MA, B8PA, B8FA, and B8TA) are solution-treated in the finished condition. Class 2 products are solution-treated and strain-hardened.

TABLE 4
RECOMMENDED TEST TEMPERATURE FOR STOCK PARTS

Grade	Test Temperature °F	Test Temperature °C
L7M, L70, L71, L72, L73	−100	−73
L7, L7A, L7B, L7C	−150	−101
L43	−150	−101
L1	−100	−73

TABLE 5
PERMISSIBLE VARIATIONS IN SIZE OF HOT-ROLLED BARS

Specified Size, in. [mm]	Permissible Variations from Specified Size: Over in.	Over mm	Under in.	Under mm	Out-of-Round in.	Out-of-Round mm
5/16 [8] and under	0.005	0.13	0.005	0.13	0.008	0.20
Over 5/16 to 7/16 [11], incl	0.006	0.15	0.006	0.15	0.009	0.23
Over 7/16 to 5/8 [16], incl	0.007	0.18	0.007	0.18	0.010	0.25
Over 5/8 to 7/8 [22], incl	0.008	0.20	0.008	0.20	0.012	0.30
Over 7/8 to 1 [25], incl	0.009	0.23	0.009	0.23	0.013	0.33
Over 1 to 1 1/8 [29], incl	0.010	0.25	0.010	0.25	0.015	0.38
Over 1 1/8 to 1 1/4 [32], incl	0.011	0.28	0.011	0.28	0.016	0.41
Over 1 1/4 to 1 3/8 [35], incl	0.012	0.30	0.012	0.30	0.018	0.46
Over 1 3/8 to 1 1/2 [38], incl	0.014	0.36	0.014	0.36	0.021	0.53
Over 1 1/2 to 2 [50], incl	1/64	0.40	1/64	0.40	0.023	0.58
Over 2 to 2 1/2 [65.0], incl	1/32	0.79	0	0	0.023	0.58

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Impact Properties

S1.1 When impact properties are desired for austenitic steel grades exempt from testing under 6.2.1, test shall be made as agreed between the manufacturer and the purchaser.

S2. Marking

S2.1 Grade and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts and studs smaller than ¼ in. [6 mm] in diameter and for ¼ in. [6 mm] studs requiring more than a total of three symbols, the marking shall be a matter of agreement between the purchaser and manufacturer.

S3. Lateral Expansion

S3.1 When lateral expansion measurements for ferritic steels are required in addition to the energy absorption requirements of 6.2.1.1, the minimum value for each specimen of a set must be .015 in. [0.38 mm]. The test temperature shall be specified by the purchaser and agreed upon by the producer.

NOTE S1—Grades L7, L7A, L7B will generally have difficulty meeting the minimum value at −150°F [−101°C]. Grade L43 may be preferred.

APPENDIX

(Nonmandatory Information)

X1.1 STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Stain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars or wire to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar, so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening.

X1.2 Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined. The minimum bar size that can be used, however, is established by the configuration of the fastener, so that the configuration can affect the strength of the fastener.

X1.3 For example, a stud of a particular alloy and size may be machined from a smaller diameter bar than a bolt of the same alloy and size because a larger diameter bar is required to accommodate the head of the bolt. The stud, therefore, is likely to be stronger than the same size bolt in a given alloy.

SPECIFICATION FOR STRUCTURAL BOLTS, STEEL, HEAT TREATED, 120/105 KSI MINIMUM TENSILE STRENGTH

SA-325

(Identical to ASTM Specification A 325-94 except for editorial differences in para. 4.3.4.) 98

1. Scope

1.1 This specification covers two types of quenched and tempered steel structural bolts having a minimum tensile strength of 120 ksi for sizes 1.0 in. and less and 105 ksi for sizes over 1.0 to 1½ in. inclusive.

1.2 The bolts are intended for use in structural connections. These connections are covered under the requirements of the Specification for Structural Joints Using ASTM A 325 or A 490 Bolts, approved by the Research Council on Structural Connections of the Engineering Foundation.

1.3 The bolts are furnished in sizes ½ to 1½ in. inclusive. They are designated by Type denoting chemical composition as follows:

Type	Description
Type 1	Medium carbon, carbon boron, or medium carbon alloy steel.
Type 2	Withdrawn in November 1991.
Type 3	Weathering steel. Atmospheric corrosion resistance and weathering characteristics are comparable to that of steels in Specifications A 242/A 242M, A 588/A 588M, and A 709/A 709M. The atmospheric corrosion resistance of these steels is substantially better than that of carbon steel with or without copper addition (see 5.2). When properly exposed to the atmosphere, these steels can be used bare (uncoated) for many applications.

NOTE 1—Bolts for general applications, including anchor bolts, are covered by Specification A 449. Also refer to Specification A 449 for quenched and tempered steel bolts and studs with diameters greater than 1½ in., but with similar mechanical properties.

NOTE 2—A complete metric companion to Specification A 325 has been developed — Specification A 325M; therefore no metric equivalents are presented in this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service

A 242/A 242M Specification for High-Strength Low-Alloy Structural Steel

A 449 Specification for Quenched and Tempered Steel Bolts and Studs

A 490 Specification for Heat-Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength

A 563 Specification for Carbon and Alloy Steel Nuts

A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point to 4 in. (100 mm) Thick

A 709/A 709M Specification for Structural Steel for Bridges

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

D 3951 Practice for Commercial Packaging

F 436 Specification for Hardened Steel Washers

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series
F 959 Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners
G 101 Guide for Estimating the Atmospheric Corrosion Resistance of Low Alloy Steels

2.2 *ANSI/ASME Standards:*
B1.1 Unified Screw Threads
B18.2.1 Square and Hex Bolts and Screws
B18.18.3M Inspection and Quality Assurance for Special Purpose Fasteners

2.3 *Military Standard:*
MIL-STD 105 Sampling Procedure and Tables for Inspection by Attributes

3. Ordering Information

3.1 Orders for bolts under this specification shall include the following:

3.1.1 Quantity (number of pieces of bolts and accessories),

3.1.2 Size, including nominal bolt diameter and length (see 3.1.3.1)

3.1.2.1 Bolts threaded full length, specify Supplementary Requirements S1.

3.1.3 *Name of product.*

3.1.3.1 Heavy Hex Structural Bolts are supplied unless otherwise specified. For bolts other than Heavy Hex Structural, dimensional requirements must be specified on the purchase inquiry and order. The thread length may not be changed except as provided in Supplementary Requirements S1.

3.1.4 Type of bolt, that is Type 1 or 3.

3.1.5 ASTM designation and year of issue.

3.1.6 Accessories such as nuts and washers, when required.

3.1.7 *Zinc Coating* — Specify the zinc coating process required, for example, hot dip, mechanically deposited or no preference (see 4.3).

3.1.8 *Other Finishes* — Specify other protective finish, if required.

3.1.9 Test reports if required (see Section 14).

3.1.10 Special requirements.

NOTE 3—A typical ordering description follows: 1000 pieces 1 in. dia × 4 in. long Heavy Hex Structural Bolt, *Type 1 ASTM A 325-XX;* each with one Hardened Washer, ASTM F 436 Type 1; and one Heavy Hex Nut, ASTM A 563 Grade DH. Each component hot dip zinc coated. Nuts lubricated.

3.2 *Recommended Nuts:*

3.2.1 Unless otherwise specified, all nuts used on these bolts shall conform to the requirements of Specification A 194/A 194M or A 563, shall be heavy hex, and shall be of the class and surface finish for each type of bolt as follows:

Bolt Type and Finish	Nut Class and Finish
1, plain (noncoated)	A 563-C, C3, D, DH, DH3, plain A 194-2, 2H, plain
1, zinc-coated	A 563-DH, zinc coated A194-2, 2H, zinc coated, (see 3.2.2)
3, plain	A 563-C3, DH3, plain

3.2.2 When Specification A 194/A 194M Gr. 2H zinc coated nuts are supplied, the zinc coating, overtapping, lubrication, and rotational capacity testing shall be in accordance with Specification A 563.

3.3 Unless otherwise specified, all washers used on these bolts shall conform to the requirements of Specifications F 436 or F 959 and shall be of a surface finish for each type of bolt as follows:

Bolt Type and Finish	Washer Finish
1, plain (uncoated)	plain (uncoated)
1, zinc-coated	zinc coated
3, plain	weathering steel, plain

4. Materials and Manufacture

4.1 *Heat Treatment* — Bolts shall be heat treated by quenching in a liquid medium from above the austenitizing temperature and then tempering by reheating to a temperature of at least 800°F.

4.2 *Threading* — Threads of bolts may be cut or rolled.

4.3 *Zinc Coatings, Hot-Dip and Mechanically Deposited:*

4.3.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc-coating process, for example, hot dip, mechanically deposited, or no preference.

4.3.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process and the coating shall conform to the coating weight/thickness and performance requirements of Class C of Specification A 153.

4.3.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical deposition process and the coating shall conform to the coating weight/thickness and performance requirements of Class 50 of Specification B 695.

4.3.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. All components of mating fasteners (for example, bolts, nuts, and washers) shall be coated by the same zinc-coating process and the supplier's option is limited to one process per item with no mixed processes in a lot.

4.4 *Lubrication* — When zinc coated nuts are ordered with the bolts, the nuts shall be lubricated in accordance with Specification A 563 Supplementary Requirement S1 to minimize galling.

4.5 *Secondary Processing* — If heat treatment, zinc coating, lubrication, or other processing affecting properties is performed by a subcontractor, the fasteners shall be inspected after such processing by the party responsible for supplying the fasteners to the user or installer. Heat treated fasteners shall be tested for all mechanical properties; hot dip zinc coated fasteners for all mechanical properties and rotational capacity; mechanically zinc coated fasteners for rotational capacity; and lubricated fasteners for rotational capacity.

5. Chemical Composition

5.1 Type 1 bolts and studs shall be plain carbon steel, carbon/boron steel, or alloy steel, at the manufacturers option, conforming to the chemical composition specified in Table 1.

5.2 Type 3 bolts shall be weathering steel and shall conform to one of the chemical compositions specified in Table 2. The selection of the chemical composition, A, B, C, D, E, or F, shall be at the option of the bolt manufacturer. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steels.

5.3 Product analyses may be made by the purchaser from finished material representing each lot of bolts. The chemical composition thus determined shall conform to the requirements specified in 5.1 or 5.2.

5.4 Heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for bolts.

5.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 *Hardness* — The bolts shall conform to the hardness specified in Table 3.

6.2 *Tensile Properties:*

6.2.1 Bolts having a length of 3 times the diameter or longer (see 6.2.3) shall be tested full size and shall conform to the tensile strength and proof load or alternative proof load specified in Table 4.

6.2.2 Bolts having a length less than 3 times the diameter are not subject to tensile tests, except as permitted in 6.2.3.

6.2.3 Bolts having a length of 2 times the diameter or longer may be tested full size for tensile properties whenever test equipment is available. In such cases reference to "3 times the diameter" in Table 3, 6.2.1, and 6.2.2 shall be considered to be "2 times the diameter".

6.2.4 For bolts on which hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event of controversy over low hardness tests.

6.3 *Rotational Capacity (Lubricant) Test:*

6.3.1 *Definition* — The rotational capacity test is intended to evaluate the efficiency of the lubricant on zinc coated nuts in Specification A 563.

6.3.2 *Requirement* — Zinc coated bolts and zinc coated and lubricated nuts tested full size in an assembled joint in accordance with 10.2, shall not show signs of failure when subjected to the nut rotation in Table 5. The test shall be performed by the responsible

party (see Section 15) prior to shipment after zinc coating and lubrication of nuts.

6.3.3 *Acceptance Criteria* — The lubricant shall be considered as nonconforming if the joint fails to pass one or more of the requirements specified below:

6.3.3.1 Inability to assemble to the nut rotation in Table 5 and remove the nut following the test.

6.3.3.2 Shear failure of the threads as determined by visual examination of bolt and nut threads following removal.

6.3.3.3 Torsional failure of the bolt. Elongation of the bolt, in the threads between the nut and bolt head, is to be expected at the required rotation and is not to be classified as a failure.

7. Dimensions

7.1 The bolts shall be full-body conforming to the dimensions for Heavy Hex Structural Bolts specified in ANSI/ASME B18.2.1.

7.1.1 Heavy Hex Structural Bolts shall be supplied, unless otherwise specified. For bolts other than Heavy Hex Structural, dimensional requirements must be specified on the purchase inquiry and order. The thread length may not be changed except as provided in Supplementary Requirement S1. Special thread lengths can be ordered under Specification A 449.

7.2 Threads shall be the Unified Coarse Thread Series as specified in ANSI/ASME B1.1, and shall have Class 2A tolerances. When specified, 8-pitch thread series may be used on bolts over 1 in. in diameter.

7.3 Unless otherwise specified, bolts to be used with nuts or tapped holes which have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot-dip or mechanically deposited zinc coating. After zinc coating, the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

Diameter, in.[A]	Oversize Limit, in.[A]
1/4	0.016
5/16, 3/8	0.017
7/16, 1/2	0.018
9/16 to 3/4 incl	0.020
7/8	0.022
1.0 to 1 1/4 incl	0.024
1 3/8, 1 1/2	0.027

[A] These values are the same as the overtapping required for zinc-coated nuts in Specification A 563.

7.4 The gaging limit for bolts shall be verified during manufacture. In case of dispute, a calibrated thread ring gage of the same size as the oversize limit in 7.3 (Class X tolerance, gage tolerance plus) shall be used to verify compliance. Assembly of the gage, or the nut described above, must be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, shall be performed at the frequency described in Table 6.

8. Workmanship

8.1 Surface discontinuity limits shall be in accordance with Specification F 788/F 788M.

9. Number of Tests and Retests

9.1 *Testing Responsibility:*

9.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the production lot identification control quality assurance plan in 9.2 through 9.6.

9.1.2 When bolts are furnished by a source other than the manufacturer, the Responsible Party as defined in 15.1 shall be responsible for assuring all tests have been performed and the bolts comply with the requirements of this specification (see 4.5).

9.2 *Purpose of Lot Inspection* — The purpose of a production lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

9.3 *Production Lot Method* — All bolts shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each production lot of bolts from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

9.4. *Production Lot Definition* — A production lot, for purposes of assigning an identification number and from which test samples shall be selected, shall consist of all bolts processed essentially together through all

operations to the shipping container that are of the same nominal size, the same nominal length, and produced from the same mill heat of steel.

9.5 *Number of Tests*

9.5.1 The minimum number of tests from each production lot shall conform to the following:

Test	Number of Pieces in Production Lot	Number of Tests	Acceptance Number
	800 and less	1	0
Hardness	801 to 8,000	2	0
Tensile	8,001 to 35,000	3	0
Proof Load	35,001 to 150,000	8	0
	150,001 and over	13	0
Rotational Capacity	150,000 and less	2	0
Coating Weight	250,000 and less	4	0
Dimensions	In accordance with the manufacturers standard quality control practices. In the event of dispute, acceptance shall be based on the requirements for Final Inspection-Non Destructive shown in ASME/ANSI B18.18.3M		
Thread fit			
Non Coated	Same as Dimensions		
Coated	In accordance with 7.4 and Table 6		
Head Bursts	In accordance with Section 11 and Table 7		

9.6 When tested in accordance with the required sampling plan, a lot shall be rejected if any of the test specimens fail to meet the applicable test requirements.

10. Test Methods

10.1 *Tensile and Hardness:*

10.1.1 Tensile and hardness tests shall be conducted in accordance with Test Methods F 606 using the wedge tension testing of full size product method to determine full size tensile strength.

10.1.2 Proof load shall preferably be determined using Method 1, Length Measurement.

10.1.3 Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body.

10.2 *Rotational Capacity* — The zinc-coated bolt shall be placed in a steel joint or tension measuring device and assembled with a zinc-coated washer and a zinc-coated and lubricated nut with which the bolt is intended to be used. The nut shall have been provided with the lubricant described in the last paragraph of the Manufacturing Processes section of Specification A 563. The joint shall be one or more flat structural steel plates or fixture stack up with a total thickness, including the washer, such that 3 to 5 full threads of the bolt are located between the bearing surfaces of the bolt head and nut. The hole in the joint shall have the same nominal diameter as the hole in the washer. The initial tightening of the nut shall produce a load in the bolt not less than 10% of the specified proof load. After initial tightening, the nut position shall be marked relative to the bolt, and the rotation shown in Table 5 shall be applied. During rotation, the bolt head shall be restrained from turning.

11. Visual Inspection for Head Bursts

11.1 *Requirement* — Each lot shall be visually inspected for head bursts and shall meet an acceptable quality level of 2.5 as specified in Table 7.

11.2 *Testing* — AQL sampling and inspection shall be conducted in accordance with the sample size, acceptance, and rejection values specified in Table 7. Samples shall be picked at random.

11.3 *Definitions:*

11.3.1 *Burst* — A burst is an open break in the metal (material). Bursts can occur on the flats or corners of the heads of bolts.

11.3.2 *Defective Bolt* — A defective bolt, for the purposes of the visual inspection for bursts, shall be any bolt that contains a burst in the flat of the head which extends into the top crown surface of the head (chamfer circle) or the under-head bearing surface. In addition, bursts occurring at the intersection of two wrenching flats shall not reduce the width across corners below the specified minimum.

11.3.3 *Lot* — A lot, for the purposes of visual inspection, shall consist of all bolts of one type having the same nominal diameter and length made from the same heat of material and by the same production process and subsequently submitted for final inspection at one time.

11.4 *Acceptance Criteria:*

11.4.1 *Manufacturer* — If the number of defective bolts found during inspection by the manufacturer is greater than the acceptance number given in Table 7 for the sample size, all bolts in the lot shall be visually inspected and all defective bolts shall be removed and destroyed.

11.4.2 *Purchaser* — If the number of defective bolts found during inspection by the purchaser is greater than the acceptance number given in Table 7 for the sample size, the lot shall be subject to rejection.

12. Inspection

12.1 If the inspection described in 12.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works, or suppliers place of business, that concern the manufacture or supply of the material ordered. The manufacturer or supplier shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the manufacturers works or suppliers place of business.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier may make claim for a rehearing.

14. Certification

14.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party as defined in Section 15, shall furnish the purchaser a test report which includes the following:

14.1.1 Heat analysis and heat number,

14.1.2 Results of hardness, tensile, and proof load tests,

14.1.3 Results of rotational capacity tests. This shall include the test method used (solid plate or tension measuring device); and the lubricant present for zinc coated nuts when shipped with zinc coated bolts,

14.1.4 Zinc coating measured coating weight/thickness for coated bolts,

14.1.5 Results of visual inspection for bursts,

14.1.6 Statement of compliance with dimensional and thread fit requirements,

14.1.7 Lot number and purchase order number,

14.1.8 Complete mailing address of responsible party, and

14.1.9 Title and signature of the individual assigned certification responsibility by the company officers.

14.2 Failure to include all the required information on the test report shall be cause for rejection.

15. Responsibility

15.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

16. Product Marking

16.1 *Manufacturers Identification* — All Type 1 and 3 bolts shall be marked by the manufacturer with a unique identifier to identify the manufacturer or private label distributor, as appropriate. **98**

16.2 *Grade Identification:*

16.2.1 Type 1 bolts shall be marked "A 325". Additionally, the bolts may be marked with 3 radial lines 120 degrees apart.

16.2.2 Type 3 bolts shall be marked A 325 with the A 325 underlined. The manufacturer may add other distinguishing marks indicating the bolt is a weathering type.

16.3 *Marking Location and Methods* — All marking shall be located on the top of the bolt head and may be either raised or depressed at the manufacturers option.

16.4 *Acceptance Criteria* — Bolts which are not marked in accordance with these provisions shall be considered nonconforming and subject to revision.

17. Packaging and Package Marking

17.1 *Packaging:*

17.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

17.1.2 When zinc coated nuts are included on the same order as zinc coated bolts, the bolts and nuts shall be shipped in the same container.

17.1.3 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

17.2 *Package Marking:*

17.2.1 Each shipping unit shall include or be plainly marked with the following information:

17.2.1.1 ASTM designation and type,

17.2.1.2 Size,

17.2.1.3 Name and brand or trademark of the manufacturer,

17.2.1.4 Number of pieces,

17.2.1.5 Lot number,

17.2.1.6 Purchase order number, and

17.2.1.7 Country of origin.

18. Keywords

18.1 bolts; carbon steel; steel; structural; weathering steel

TABLE 1
CHEMICAL REQUIREMENTS FOR TYPE 1 BOLTS

	Composition, %			
	Carbon or Alloy Steel		Carbon Boron Steel	
Element	Heat Analysis	Product Analysis	Heat Analysis	Product Analysis
Carbon	0.30–0.52	0.28–0.55	0.30–0.52	0.28–0.55
Manganese, min	0.60	0.57	0.60	0.57
Phosphorus, max				
C and C Boron	0.040	0.048	0.040	0.048
Alloy Steel	0.035	0.040	0.035	0.040
Sulfur				
C and C Boron	0.050	0.058	0.050	0.058
Alloy Steel	0.040	0.045	0.040	0.045
Silicon				
Alloy Steel	0.15–0.35	0.13–0.37	—	—
Boron	[A]	[A]	0.0005–0.003	0.0005–0.003
Alloying Elements	Permitted		—	—

[A] Boron shall not be added.

TABLE 2
CHEMICAL REQUIREMENTS FOR TYPE 3 BOLTS

	Composition, %					
	Type 3 Bolts[A]					
Element	A	B	C	D	E	F
Carbon:						
Heat analysis	0.33–0.40	0.38–0.48	0.15–0.25	0.15–0.25	0.20–0.25	0.20–0.25
Product analysis	0.31–0.42	0.36–0.50	0.14–0.26	0.14–0.26	0.18–0.27	0.19–0.26
Manganese:						
Heat analysis	0.90–1.20	0.70–0.90	0.80–1.35	0.40–1.20	0.60–1.00	0.90–1.20
Product analysis	0.86–1.24	0.67–0.93	0.76–1.39	0.36–1.24	0.56–1.04	0.86–1.24
Phosphorus:						
Heat analysis	0.040 max	0.06–0.12	0.035 max	0.040 max	0.040 max	0.040 max
Product analysis	0.045 max	0.06–0.125	0.040 max	0.045 max	0.045 max	0.045 max
Sulfur:						
Heat analysis	0.050 max	0.050 max	0.040 max	0.050 max	0.040 max	0.040 max
Product analysis	0.055 max	0.055 max	0.045 max	0.055 max	0.045 max	0.045 max
Silicon:						
Heat analysis	0.15–0.35	0.30–0.50	0.15–0.35	0.25–0.50	0.15–0.35	0.15–0.35
Product analysis	0.13–0.37	0.25–0.55	0.13–0.37	0.20–0.55	0.13–0.37	0.13–0.37
Copper:						
Heat analysis	0.25–0.45	0.20–0.40	0.20–0.50	0.30–0.50	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.17–0.43	0.17–0.53	0.27–0.53	0.27–0.63	0.17–0.43
Nickel:						
Heat analysis	0.25–0.45	0.50–0.80	0.25–0.50	0.50–0.80	0.30–0.60	0.20–0.40
Product analysis	0.22–0.48	0.47–0.83	0.22–0.53	0.47–0.83	0.27–0.63	0.17–0.43
Chromium:						
Heat analysis	0.45–0.65	0.50–0.75	0.30–0.50	0.50–1.00	0.60–0.90	0.45–0.65
Product analysis	0.42–0.68	0.47–0.83	0.27–0.53	0.45–1.05	0.55–0.95	0.42–0.68
Vanadium:						
Heat analysis	. . .	. . .	0.020 min	. . .	. . .	. . .
Product analysis	. . .	. . .	0.010 min	. . .	. . .	. . .
Molybdenum:						
Heat analysis	. . .	0.06 max	. . .	0.10 max	. . .	. . .
Product analysis	. . .	0.07 max	. . .	0.11 max	. . .	. . .
Titanium:						
Heat analysis	. . .	. . .	. . .	0.05 max	. . .	. . .
Product analysis	. . .	. . .	. . .	. . .	. . .	. . .

[A] A, B, C, D, E, and F are classes of material used for Type 3 bolts. Selection of a class shall be at the option of the bolt manufacturer.

TABLE 3
HARDNESS REQUIREMENTS FOR BOLTS

Bolt Size, in.	Bolt Length, in.	Brinell		Rockwell C	
		Min	Max	Min	Max
1/2 to 1, incl	Less than 3D[A]	253	319	25	34
	3D and over	—	319	—	34
1 1/8 to 1 1/2, incl	Less than 3D[A]	223	286	19	30
	3D and over	—	286	—	30

[A] Bolts having a length less than 3 times the diameter are subject only to minimum/maximum hardness. Such lengths cannot be reasonably tensile tested.

D = Nominal diameter or thread size.

TABLE 4
TENSILE REQUIREMENTS FOR FULL SIZE BOLTS

Bolt Size, Threads per Inch and Series Designation	Stress Area,[A] in.^{2}	Tensile Strength[B] min, lbf	Proof Load,[B] Length Measurement Method	Alternative Proof Load,[B] Yield Strength Method, min
Column 1	Column 2	Column 3	Column 4	Column 5
1/2–13 UNC	0.142	17 050	12 050	13 050
5/8–11 UNC	0.226	27 000	19 200	20 800
3/4–10 UNC	0.334	40 100	28 400	30 700
7/8–9 UNC	0.462	55 450	39 250	42 500
1–8 UNC	0.606	72 700	51 500	55 750
1 1/8–7 UNC	0.763	80 100	56 450	61 800
1 1/8–8 UN	0.790	82 950	58 450	64 000
1 1/4–7 UNC	0.969	101 700	71 700	78 500
1 1/4–8 UN	1.000	105 000	74 000	81 000
1 3/8–6 UNC	1.155	121 300	85 450	93 550
1 3/8–8 UN	1.233	129 500	91 250	99 870
1 1/2–6 UNC	1.405	147 500	104 000	113 800
1 1/2–8 UN	1.492	156 700	110 400	120 850

[A] The stress area is calculated as follows:

$$As = 0.7854\,[D - (0.9743/n)]^2$$

where:
As = stress area, in.^{2},
D = nominal bolt size, and
n = threads per inch.

[B] Loads tabulated are based on the following:

Bolt Size, in.	Column 3	Column 4	Column 5
1/2 to 1, incl	120 000 psi	85 000 psi	92 000 psi
1 1/8 to 1 1/2, incl	105 000 psi	74 000 psi	81 000 psi

98

TABLE 5
ROTATIONAL CAPACITY TEST FOR ZINC-COATED BOLTS

Bolt Length, in.	Nominal Nut Rotation, degrees (Turn)
Up to and including 4 × dia	240 (2/3)
Over 4 × dia, but not exceeding 8 × dia	360 (1)
Over 8 × dia	420 (1 1/6)

TABLE 6
SAMPLE SIZES AND ACCEPTANCE NUMBERS FOR INSPECTION OF HOT DIP OR MECHANICALLY DEPOSITED ZINC-COATED THREADS

Lot Size	Sample Size[A,B]	Acceptance Number[A]
2 to 90	13	1
91 to 150	20	2
151 to 280	32	3
281 to 500	50	5
501 to 1 200	80	7
1 201 to 3 200	125	10
3 201 to 10 000	200	14
10 001 and over	315	21

[A] Sample sizes of acceptance numbers are extracted from "Single Sampling Plan for Normal Inspection" Table IIA, MIL-STD-105.
[B] Inspect all bolts in the lot if the lot size is less than the sample size.

TABLE 7
SAMPLE SIZES WITH ACCEPTANCE AND REJECTION NUMBERS FOR INSPECTION OF BURSTS 2.5 AQL

Lot Size	Sample Size[A,B]	Acceptance Number[A]	Rejection No.
2 to 8	2	0	1
9 to 15	3	0	1
16 to 25	5	0	1
26 to 150	20	1	2
151 to 280	32	2	3
281 to 500	50	3	4
501 to 1 200	80	5	6
1 201 to 3 200	125	7	8
3 201 to 10 000	200	10	11
10 001 to 35 000	315	14	15

[A] Sample sizes, acceptance numbers, and rejection numbers are extracted from "Single Sampling Plan for Normal Inspection" Table IIA, MIL-STD-105.
[B] Inspect all bolts in the lot if the lot size is less than the sample size.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order. Details of these supplementary requirements shall be agreed upon in writing between the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Bolts Threaded Full Length

S1.1 Bolts with nominal lengths equal to or shorter than four times the nominal bolt diameter shall be threaded full length. Bolts need not have a shoulder, and the distance from the underhead bearing surface to the first complete (full form) thread, as measured with a GO thread ring gage, assembled by hand as far as the thread will permit, shall not exceed the length of $2\frac{1}{2}$ threads for bolt sizes 1 in. and smaller, and $3\frac{1}{2}$ threads for bolt sizes larger than 1 in.

S1.2 Bolts shall be marked in accordance with Section 16, except that the symbol shall be A 325 T instead of A 325.

SPECIFICATION FOR SEAMLESS AND WELDED STEEL PIPE FOR LOW-TEMPERATURE SERVICE

SA-333/SA-333M

(Identical with ASTM Specification A 333/A 333M-94.) 98

1. Scope

1.1 This specification covers nominal (average) wall seamless and welded carbon and alloy steel pipe intended for use at low temperatures. Several grades of ferritic steel are included as listed in Table 1. Some product sizes may not be available under this specification because heavier wall thicknesses have an adverse affect on low-temperature impact properties.

1.2 Supplementary Requirement S1 of an optional nature is provided. This shall apply only when specified by the purchaser.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalent; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter" "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 671 Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures

E 23 Method for Notched Bar Impact Testing of Metallic Materials

3. General Requirements

3.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the material adequately:

4.1.1 Quantity (feet, centimetres, or number of lengths),

4.1.2 Name of material (seamless or welded pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (NPS or outside diameter and schedule number of average wall thickness),

4.1.5 Length (specific or random), (Section 12) (Permissible Variations in Length Section of Specification A 530/A 530M),

4.1.6 End finish (Ends Section of Specification A 530/A 530M),

4.1.7 Optional requirements, (heat analysis requirement in the Chemical composition Section of A 530/A 530M; 13.1.1 other temperatures for impact tests; 5.3.4 stress relieving; (see Hydrostatic Test Require-

ments Section of Specification A 530/A 530M; and 11.6 repair by welding),

4.1.8 Test report required, (Certification Section of Specification A 530/A 530M),

4.1.9 Specification designation, and

4.1.10 Special requirements or exceptions to this specification.

5. Materials and Manufacture

5.1 *Manufacture*—The pipe shall be made by the seamless or welding process with the addition of no filler metal in the welding operation. Grade 4 shall be made by the seamless process.

NOTE 2—For electric-fusion-welded pipe, with filler metal added, see Specification A 671.

5.2 *Heat Treatment:*

5.2.1 All seamless and welded pipe, other than Grade 8 and 11, shall be treated to control their microstructure in accordance with one of the following methods:

5.2.1.1 Normalize by heating to a uniform temperature of not less than 1500°F [815°C] and cool in air or in the cooling chamber of an atmosphere controlled furnace.

5.2.1.2 Normalize as in 5.2.1.1, and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

5.2.1.3 For the seamless process only, reheat and control hot working and the temperature of the hot-finishing operation to a finishing temperature range from 1550 to 1750°F [845 to 945°C] and cool in a controlled atmosphere furnace from an initial temperature of not less than 1550°F [845°C].

5.2.1.4 Treat as in 5.2.1.3 and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

5.2.1.5 Seamless pipe of Grades 1, 6 and 10 may be heat treated by heating to a uniform temperature of not less than 1500°F [815°C], followed by quenching in liquid and reheating to a suitable tempering temperature, in place of any of the other heat treatments provided for in 5.2.1.

5.2.2 Grade 8 pipe shall be heat treated by the manufacturer by either of the following methods:

5.2.2.1 *Quenched and Tempered*—Heat to a uniform temperature of 1475 ± 25°F [800 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; quench by immersion in circulating water. Reheat until the pipe attains a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air or water quench at a rate no less than 300°F [165°C]/h.

5.2.2.2 *Double Normalized and Tempered*—Heat to a uniform temperature of 1650 ± 25°F [900 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat until the pipe attains a uniform temperature of 1450 ± 25°C [790 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. [2 min/mm] of thickness but in no case less than 15 min; cool in air or water quench at a rate not less than 300°F [165°C]/h.

5.2.3 Whether to anneal Grade 11 pipe is per agreement between purchaser and supplier. When Grade 11 pipe is annealed, it shall be normalized in the range of 1400 to 1600°F [760 to 870°C].

5.2.4 Material from which test specimens are obtained shall be in the same condition of heat treatment as the pipe furnished. Material from which specimens are to be taken shall be heat treated prior to preparation of the specimens.

5.2.5 When specified in the order the test specimens shall be taken from full thickness test pieces which have been stress relieved after having been removed from the heat treated pipe. The test pieces shall be gradually and uniformly heated to the prescribed temperature, held at that temperature for a period of time in accordance with Table 2, and then furnace cooled at a temperature not exceeding 600°F [315°C]. Grade 8 shall be cooled at a minimum rate of 300°F [165°C]/h in air or water to a temperature not exceeding 600°F [315°C].

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 When Grades 1, 6, or 10 are ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted. However, the addition of elements required for the deoxidation of the steel is permitted.

7. Product Analysis

7.1 At the request of the purchaser, an analysis of one billet or two samples of flat-rolled stock from each heat or of two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following:

NPS Designator	Length of Pipe in Lot
Under 2	400 or fraction thereof
2 to 6	200 or fraction thereof
Over 6	100 or fraction thereof

7.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified.

7.3 If the analysis of one of the tests specified in 7.1 does not conform to the requirements specified, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

9. Impact Requirements

9.1 For Grades 1, 3, 4, 6, 7, 9, and 10, the notched-bar impact properties of each set of three impact specimens including specimens for the welded joint in welded pipe with wall thicknesses of 0.120 in. [3 mm] and larger, when tested at temperatures in conformance with 10.1 shall be not less than the values prescribed in Table 4. The impact test is not required for Grade 11.

9.1.1 If the impact value of one specimen is below the minimum value, or the impact values of two specimens are less than the minimum average value but not below the minimum value permitted on a single specimen, a retest shall be allowed. The retest shall consist of breaking three additional specimens and each specimen must equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedures, a retest will be allowed.

9.2 For Grade 8 each of the notched bar impact specimens shall display a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

9.2.1 When the average lateral expansion value for the three impact specimens equals or exceeds 0.015 in. [0.38 mm] and the value for one specimen is below 0.015 in. [0.38 mm] but not below 0.010 in. [0.25 mm], a retest of three additional specimens may be made. The lateral expansion of each of the retest specimens must equal or exceed 0.015 in. [0.38 mm].

9.2.2 Lateral expansion values shall be determined by the procedure in Methods and Definitions A 370.

9.2.3 The values of absorbed energy in foot-pounds and the fracture appearance in percentage shear shall be recorded for information. A record of these values shall be retained for a period of at least 2 years.

10. Lengths

10.1 If define lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft. (Note 3) with 5% 12 of 16 ft (Note 4), or in double random lengths with a minimum average of 35 ft (Note 4) and a minimum length of 22 ft (Note 4) with 5% 16 to 22 ft (Note 3).

NOTE 3—This value(s) applies when the inch-pound designation of his specification is the basis of purchase. When the "M" designation of his specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

11. Workmanship, Finish, and Appearance

11.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to assure compliance with 11.2.

11.2 Surface imperfections that penetrate more than 12½% of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

11.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

11.2.2 Repaired in accordance with the repair welding provisions of 11.6.

11.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

11.2.4 The defective pipe may be rejected.

11.3 To provide a workmanlike finish and basis for evaluating conformance with 11.2, the pipe manufacturer shall remove by grinding the following:

11.3.1 Mechanical marks, abrasions and pits, any of which imperfections are deeper than $\frac{1}{16}$ in. [1.6 mm], and

11.3.2 Visual imperfections commonly referred to as scabs, scams, laps, tears, or slivers found by exploration in accordance with 11.1 to be deeper than 5% of the nominal wall thickness.

11.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 11.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

11.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

11.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

11.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

11.7 The finished pipe shall be reasonably straight.

12. Number of Tests Required

12.1 *Transverse or Longitudinal Tensile Test and Flattening Test*—For material heat treated in a batch-type furnace, tests shall be made on 5% of the pipe from each lot. When heat treated by the continuous process, tests shall be made on a sufficient number of pipe to constitute 5% of the lot, but in no case less than 2 pipes.

NOTE 4—The term "lot" applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace. When final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge.

12.2 *Hydrostatic Test*—Each length of pipe shall be subjected to the hydrostatic test.

12.3 *Impact Test*—One notched bar impact test, consisting of breaking three specimens, shall be made from each heat represented in a heat-treatment load on specimens taken from the finished pipe. This test shall represent only pipe from the same heat and the same heat-treatment load, the wall thicknesses of which do not exceed by more than $\frac{1}{4}$ in. [6.3 mm] the wall thicknesses of the pipe from which the test specimens are taken. If heat treatment is performed in continuous or batch-type furnaces controlled within a 50°F [30°C] range and equipped with recording pyrometers so that complete records of heat treatment are available, then one test from each heat in a continuous run only shall be required instead of one test from each heat in each heat-treatment load.

12.4 *Impact Tests (Welded Pipe)*—On welded pipe, additional impact tests of the same number as required in 12.3 or 12.4 shall be made to test the weld.

12.5 Specimens showing defects while being machined or prior to testing may be discarded and replacements shall be considered as original specimens.

12.6 Results obtained from these tests shall be reported to the purchaser or his representative.

13. Specimens for Impact Test

13.1 Notched bar impact specimens shall be of the simple beam, Charpy-type, in accordance with Test Methods E 23, Type A with a V notch. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable subsize specimens shall be used. Charpy specimens of width along the notch larger than 0.394 in. [10 mm] or smaller than 0.099 in. [2.5 mm] are not provided for in this specification.

13.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the pipe while the axis of the notch shall be perpendicular to the surface. On wall

thicknesses of 1 in. [25 mm] or less, the specimens shall be obtained with their axial plane located at the midpoint; on wall thicknesses over 1 in. [25 mm], the specimens shall be obtained with their axial plane located ½ in. [12.5 mm] from the outer surface.

13.3 When testing welds the specimen shall be, whenever diameter and thickness permit, transverse to the longitudinal axis of the pipe with the notch of the specimen in the welded joint and perpendicular to the surface. When diameter and thickness do not permit obtaining transverse specimens, longitudinal specimens in accordance with 13.2 shall be obtained; the bottom of the notch shall be located at the weld joint.

14. Impact Test

14.1 Except when the size of the finished pipe is insufficient to permit obtaining subsize impact specimens, all material furnished to this specification and marked in accordance with Section 15 shall be tested for impact resistance at the minimum temperature for the respective grades as shown in Table 5.

14.1.1 Special impact tests on individual lots of material may be made at other temperatures as agreed upon between the manufacturer and the purchaser.

14.1.2 When subsize Charpy impact specimens are used and the width along the notch is less than 80% of the actual wall thickness of the original material, the specified Charpy impact test temperature for Grades 1, 3, 4, 6, 7, 9, and 10 shall be lower than the minimum temperature shown in Table 5 for the respective grade. Under these circumstances the temperature reduction values shall be by an amount equal to the difference (as shown in Table 6) between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to the Charpy specimen width actually tested. Appendix XI shows some examples of how the temperature reductions are determined.

14.2 The notched bar impact test shall be made in accordance with the procedure for the simple beam, Charpy-type test of Methods E 23.

14.3 Impact tests specified for temperatures lower than 70°F [20°C] should be made with the following precautions. The impact test specimens as well as the handling tongs shall be cooled a sufficient time in a suitable container so that both reach the desired temperature. The temperature shall be measured with thermocouples, thermometers, or any other suitable devices and shall be controlled within 3°F [2°C]. The specimens shall be quickly transferred from the cooling device to the anvil of the Charpy impact testing machine and broken with a time lapse of not more than 5 s.

15. Product Marking

15.1 Except as modified in 15.1.1, in addition to the marking prescribed in Specification A 530/A 530M, the marking shall include whether hot finished, cold drawn, seamless or welded, the schedule number and the letter “LT” followed by the temperature at which the impact tests were made, except when a lower test temperature is required because of reduced specimen size, in which case, the higher impact test temperature applicable to a full-size specimen should be marked.

15.1.1 When the size of the finished pipe is insufficient to obtain subsize impact specimens, the marking shall not include the letters LT followed by an indicated test temperature unless Supplementary Requirement S1 is specified.

15.1.2 When the pipe is furnished in the quenched and tempered condition, the marking shall include the letters “QT”, and the heat treatment condition shall be reported to the purchaser or his representative.

Keywords

16.1 low temperature service; seamless steel pipe; stainless steel pipe; steel pipe; temperature service applications—low

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %								
	Grade 1[A]	Grade 3	Grade 4	Grade 6[A]	Grade 7	Grade 8	Grade 9	Grade 10	Grade 11
Carbon, max	0.30	0.19	0.12	0.30	0.19	0.13	0.20	0.20	0.10
Manganese	0.40–1.06	0.31–0.64	0.50–1.05	0.29–1.06	0.90 max	0.90 max	0.40–1.06	1.15–1.50	0.60 max
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.035	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.015	0.025
Silicon	. . .	0.18–0.37	0.08–0.37	0.10 min	0.13–0.32	0.13–0.32	. . .	0.10–0.35	0.35 max
Nickel	. . .	3.18–3.82	0.47–0.98	. . .	2.03–2.57	8.40–9.60	1.60–2.24	0.25 max	35.0–37.0
Chromium	. . .	. . .	0.44–1.01	. . .	. . .	. . .	. . .	0.15 max	0.50 max
Copper	. . .	. . .	0.40–0.75	. . .	. . .	. . .	0.75–1.25	0.15 max	. . .
Aluminum	. . .	. . .	0.04–0.30	. . .	. . .	. . .	. . .	0.06 max	. . .
Vanadium, max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.12	. . .
Columbium, max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.05	. . .
Molybdenum, max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.05	0.50 max
Cobalt	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.50 max

[A] For each reduction of 0.01% carbon below 0.30%, an increase of 0.05% manganese above 1.06% would be permitted to a maximum of 1.35% manganese.

TABLE 2
STRESS RELIEVING OF TEST PIECES

Metal Temperature[A,B]				Minimum Holding Time, h/in. [min/mm] of Thickness
Grades 1, 3, 6, 7, and 10		Grade 4[C]		
°F	°C	°F	°C	
1100	600	1150	620	1 [2.4]
1050	565	1100	600	2 [4.7]
1000	540	1050	565	3 [7.1]

NOTES:
[A] For intermediate temperatures, the holding time shall be determined by straight-line interpolation.
[B] Grade 8 shall be stress relieved at 1025 to 1085°F, [550 to 585°C], held for a minimum time of 2 h for thickness up to 1.0 in. [25.4 mm], plus a minimum of 1 h for each additional inch [25.4 mm] of thickness and cooled at a minimum rate of 300°F [165°C]/h in air or water to a temperature not exceeding 600°F [315°C].
[C] Unless otherwise specified, Grade 4 shall be stress relieved at 1150°F [620°C].

TABLE 3
TENSILE REQUIREMENTS

	Grade 1		Grade 3		Grade 4		Grade 6		Grade 7		Grade 8		Grade 9		Grade 10		Grade 11	
	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa
Tensile strength, min	55 000	380	65 000	450	60 000	415	60 000	415	65 000	450	100 000	690	63 000	435	80 000	550	65 000	450
Yield strength, min	30 000	205	35 000	240	35 000	240	35 000	240	35 000	240	75 000	515	48 000	315	65 000	450	35 000	240
	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	
Elongation in 2 in. or 50 mm, (or 4D), min, %:																		
Basic minimum elongation for walls $^{5}/_{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	35	25	30	20	30	16.5	30	16.5	30	22	22	...	28	...	22	...	18[A]	
When standard round 2-in. or 50-mm gage length or proportionally smaller size test specimen with the gage length equal to 4D (4 times the diameter) is used	28	20	22	14	22	12	22	12	22	14	16	...	...	...	16	...	...	
For strip tests, a deduction for each $^{1}/_{32}$ in. [0.8 mm] decrease in wall thickness below $^{5}/_{16}$ in. [8 mm] from the basic minimum elongation of the following percentage	1.75[B]	1.25[B]	1.50[B]	1.00[B]	1.50[B]	1.00[B]	1.50[B]	1.00[B]	1.50[B]	1.00[B]	1.25[B]	...	1.50[B]	...	1.25[B]	...	...	

[A] Elongation of Grade 11 is for walls and small sizes tested in full section.
[B] The following table gives the calculated minimum values

TABLE 3 (CONT'D)
TENSILE REQUIREMENTS

Wall Thickness		Elongation in 2 in. or 50 mm, min, %[C]															
		Grade 1		Grade 3		Grade 4		Grade 6		Grade 7		Grade 8		Grade 9		Grade 10	
in.	mm	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse
5/16 (0.312)	8	35	25	30	20	30	16	30	16	30	22	22	...	28	...	22	...
9/32 (0.281)	7.2	33	24	28	19	28	15	28	15	28	21	21	...	26	...	21	...
1/4 (0.250)	6.4	32	23	27	18	27	15	27	15	27	20	20	...	25	...	20	...
7/32 (0.219)	5.6	30	...	26	...	26	...	26	...	26	...	18	...	24	...	18	...
3/16 (0.188)	4.8	28	...	24	...	24	...	24	...	24	...	17	...	22	...	17	...
5/32 (0.156)	4	26	...	22	...	22	...	22	...	22	...	16	...	20	...	16	...
1/8 (0.125)	3.2	25	...	21	...	21	...	21	...	21	...	15	...	19	...	15	...
3/32 (0.094)	2.4	23	...	20	...	20	...	20	...	20	...	13	...	18	...	13	...
1/16 (0.062)	1.6	21	...	18	...	18	...	18	...	18	...	12	...	16	...	12	...

[C] Calculated elongation requirements shall be rounded to the nearest whole number.

NOTE — The preceding table gives the computed minimum elongation values for each 1/32-in. [0.8-mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

Grade	Direction of Test	Equation
1	Longitudinal	$E = 56t + 17.50$ [$E = 2.19t + 17.50$]
	Transverse	$E = 40t + 12.50$ [$E = 1.56t + 12.50$]
3	Longitudinal	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32t + 10.00$ [$E = 1.25t + 10.00$]
4	Longitudinal	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32t + 6.50$ [$E = 1.25t + 6.50$]
6	Longitudinal	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32t + 6.50$ [$E = 1.25t + 6.50$]
7	Longitudinal	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32t + 11.00$ [$E = 1.25t + 11.00$]
8 and 10	Longitudinal	$E = 40t + 9.50$ [$E = 1.56t + 9.50$]
9	Longitudinal	$E = 48t + 13.00$ [$E = 1.87t + 13.00$]

where:

E = elongation in 2 in. or 50 mm, in %, and

t = actual thickness of specimen, in. [mm].

TABLE 4
IMPACT REQUIREMENTS FOR GRADES 1, 3, 4, 6, 7, 9, AND 10

Size of Specimen, mm	Minimum Average Notched Bar Impact Value of Each Set of Three Specimens[A]		Minimum Notched Bar Impact Value of One Specimen Only of a Set[A]	
	ft-lbf	J	ft-lbf	J
10 by 10	13	18	10	14
10 by 7.5	10	14	8	11
10 by 6.67	9	12	7	9
10 by 5	7	9	5	7
10 by 3.33	5	7	3	4
10 by 2.5	4	5	3	4

[A] Straight line interpolation for intermediate values is permitted.

TABLE 5
IMPACT TEMPERATURE

Grade	Minimum Impact Test Temperature	
	°F	°C
1	−50	−45
3	−150	−100
4	−150	−100
6	−50	−45
7	−100	−75
8	−320	−195
9	−100	−75
10	−75	−60

TABLE 6
IMPACT TEMPERATURE REDUCTION

Specimen Width Along Notch or Actual Material Thickness		Temperature Reduction, Degrees Colder[A]	
in.	mm	°F	°C
0.394	10 (standard size)	0	0
0.354	9	0	0
0.315	8	0	0
0.295	7.5 (3/4 std. size)	5	3
0.276	7	8	4
0.262	6.67 (2/3 std. size)	10	5
0.236	6	15	8
0.197	5 (1/2 std. size)	20	11
0.158	4	30	17
0.131	3.33 (1/3 std. size)	35	19
0.118	3	40	22
0.099	2.5 (1/4 std. size)	50	28

[A] Straight line interpolation for intermediate values is permitted.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchase in the contract or order.

S1. Subsize Impact Specimens

S1.1 When the size of the finished pipe is insufficient to permit obtaining subsize impact specimens, testing shall be a matter of agreement between the manufacturer and the purchaser.

APPENDIX

(Nonmandatory Information)

X1. DETERMINATION OF TEMPERATURE REDUCTIONS

X1.1 Under the circumstances stated in 14.1.2, the impact test temperature specified in Table 5 must be lowered. The following examples are offered to describe the application of the provisions of 14.1.2.

X1.1.1 When subsize specimens are used (see 11.1) and the width along the notch of the subsize specimen in 80% or greater of the actual wall thickness of the original material, the provisions of 14.1.2 do not apply.

X1.1.1.1 For example, if the actual wall thickness of pipe was 0.200 in. [5.0 mm] and the width along the notch of the largest subsize specimen obtainable is 0.160 in. [4 mm] or greater, no reduction in test temperature is required.

X1.1.2 When the width along the subsize specimen notch is less than 80% of the actual wall thickness of the pipe, the required reduction in test temperature is computed by taking the difference between the temperature reduction values shown in Table 6 for the actual pipe thickness and the specimen width used.

X1.1.2.1 For example, if the pipe were 0.262 in. [6.67 mm] thick and the width along the Charpy specimen notch was 3.33 mm ($\frac{1}{3}$ standard size), the test temperature would have to be lowered by 25°F [14°C]. That is, the temperature reduction corresponding to the subsize specimen is 35°F [19°C]; the temperature reduction corresponding to the actual pipe thickness is 10°F [5°C]; the difference between these two values is the required reduction in test temperature.

SPECIFICATION FOR SEAMLESS AND WELDED CARBON AND ALLOY-STEEL TUBES FOR LOW-TEMPERATURE SERVICE

SA-334/SA-334M

(Identical with ASTM Specification A 334/A 334M-96) 98

1. Scope

1.1 This specification covers several grades of minimum-wall-thickness, seamless and welded, carbon and alloy-steel tubes intended for use at low temperatures. Some product sizes may not be available under this specification because heavier wall thicknesses have an adverse affect on low-temperature impact properties.

1.2 Supplementary Requirement S1 of an optional nature is provided. This shall apply only when specified by the purchaser.

NOTE 1 — For tubing smaller than $\frac{1}{2}$ in. [12.7 mm] in outside diameter, the elongation values given for strip specimens in Table 1 shall apply. Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in outside diameter and with a wall thickness under 0.015 in. [0.4 mm].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

98 **2.1** *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

E 23 Test Method for Notched Bar Impact Testing of Metallic Materials.

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provide herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (seamless or welded tubes),

4.1.3 Grade (Table 1),

4.1.4 Size (outside diameter and minimum wall thickness),

4.1.5 Length (specific or random),

4.1.6 Optional requirements (other temperatures, Section 13; hydrostatic or electric test, Section 12),

4.1.7 Test report required, (Certification Section of Specification A 450/A 450M),

4.1.8 Specification designation, and

4.1.9 Special requirements and any supplementary requirements selected.

5. Materials and Manufacture

5.1 The tubes shall be made by the seamless or automatic welding process with no addition of filler metal in the welding operation.

6. Heat Treatment

6.1 All seamless and welded tubes, other than Grade 8 and 11, shall be treated to control their microstructure in accordance with one of the following methods:

6.1.1 Normalize by heating to a uniform temperature of not less than 1550°F [845°C] and cool in air or in the cooling chamber of an atmosphere controlled furnace.

6.1.2 Normalize as in 10.1.1, and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

6.1.3 For the seamless process only, reheat and control hot working and the temperature of the hot-finishing operation to a finishing temperature range from 1550 to 1750°F [845 to 955°C] and cool in a controlled atmosphere furnace from an initial temperature of not less than 1550°F [845°C].

6.1.4 Treat as in 6.1.3 and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

6.2 Grade 8 tubes shall be heat treated by the manufacturer by either of the following methods.

6.2.1 *Quenched and Tempered* — Heat to a uniform temperature of 1475 ± 25°F [800 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; quench by immersion in circulating water. Reheat until the pipe attains a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air or water quench at a rate no less than 300°F [165°C]/h.

6.2.2 *Double Normalized and Tempered* — Heat to a uniform temperature of 1650 ± 25°F [900 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat until the pipe attains a uniform temperature of 1450 ± 25°F [790 ± 15°C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. [2 min/mm] of thickness but in no case less than 15 min; cool in air or water quench at a rate not less than 300°F [165°C]/h.

6.3 Material from which impact specimens are obtained shall be in the same condition of heat treatment as the finished tubes.

6.4 Whether to anneal Grade 11 tubes is per agreement between purchaser and supplier. When Grade 11 tubes are annealed they shall be normalized in the range of 1400 to 1600°F [760 to 870°C].

7. Chemical Composition

7.1 The steel shall conform to the requirements as to the chemical composition prescribed in Table 1.

7.2 When Grades 1 or 6 are ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted. However, the addition of elements required for the deoxidation of the steel is permitted. **98**

8. Product Analysis

8.1 An analysis of either one billet or one length of flat-rolled stock or one tube shall be made for each heat. The chemical composition thus determined shall conform to the requirements specified.

8.2 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock, or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Notes 2 and 3) shall be rejected or, at the option of the manufacturer, each billet, length of flat-rolled stock, or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock, or tubes which do not meet the requirements of the specifications shall be rejected.

NOTE 2 — For flattening flare, and flange requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall

include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

NOTE 3 — For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat and furnace speed.

9. Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

10. Hardness Requirements

10.1 The tubes shall have a hardness number not exceeding those prescribed in Table 4.

11. Impact Requirements

11.1 For Grades 1, 3, 6, 7 and 9, the notched-bar impact properties of each set of three impact specimens, including specimens for the welded joint in welded pipe with wall thicknesses of 0.120 in. [3 mm] and larger, when tested at temperatures in conformance with 13.1 shall be not less than the values prescribed in Table 5. The impact test is not required for Grade 11.

11.1.1 If the impact value of one specimen is below the minimum value, or the impact values of two specimens are less than the minimum average value but not below the minimum value permitted on a single specimen, a retest shall be allowed. The retest shall consist of breaking three additional specimens and each specimen must equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedures, a retest will be allowed.

11.2 For Grade 8 each of the notched bar impact specimens shall display a lateral expansion opposite the notch not less than 0.015 in. [0.38 mm].

98 **11.2.1** When the average lateral expansion value for the three impact specimens equals or exceeds 0.015 in. [0.38 mm] and the value for one specimen is below 0.015 in. [0.38 mm] but not below 0.010 in. [0.25 mm], a retest of three additional specimens may be made. The lateral expansion of each of the retest specimens must equal or exceed 0.015 in. [0.38 mm].

11.2.2 Lateral expansion values shall be determined in accordance with Test Methods and Definitions A 370.

11.2.3 The values of absorbed energy in foot-pounds and the fracture appearance in percentage shear shall be recorded for information. A record of these values shall be retained for a period of at least 2 years.

12. Number of Tests Required

12.1 *Tension Test* — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 3).

12.2 *Flattening Test* — One flattening test shall be made on specimens from each end of one finished tube of each lot (Note 2) but not the one used for the flare or flange test.

12.3 *Flare Test (Seamless Tubes)* — One flare test shall be made on specimens from each end of one finished tube of each lot (Note 2), but not the one used for the flattening test.

12.4 *Flange Test (Welded Tubes)* — One flange test shall be made on specimens from each end of one finished tube of each lot (Note 2), but not the one used for the flattening test.

12.5 *Reverse Flattening Test* — For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

12.6 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 3).

12.7 *Hydrostatic or Nondestructive Electric Test* — Each seamless tube shall be subjected to the hydrostatic test, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser. Each welded tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

12.8 *Impact Test* — One notched-bar impact, test, consisting of breaking three specimens, shall be made from each heat represented in a heat-treatment load on specimens taken from the finished tube. This test shall represent only tubes from the same heat, which have wall thicknesses not exceeding by more than $\frac{1}{4}$ in. [6.3 mm] the wall thicknesses of the tube from which the test specimens are taken. If heat treatment is per-

formed in continuous or batch-type furnaces controlled within a 50°F [30°C] range and equipped with recording pyrometers which yield complete heat-treatment records, then one test from each heat in a continuous run only shall be required instead of one test from each heat in each heat-treatment load.

12.9 *Impact Tests (Welded Tubes)* — On welded tube, additional impact tests of the same number as required in 15.8 shall be made to test the weld.

12.10 Specimens showing defects while being machined or prior to testing may be discarded and replacements shall be considered as original specimens.

13. Specimens for Impact Test

13.1 Notched-bar impact specimens shall be of the simple beam, Charpy-type, in accordance with Methods E 23, Type A, with a V notch. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable subsize specimens shall be used. Charpy specimens of width along the notch larger than 0.394 in. [10 mm] or smaller than 0.099 in. [2.5 mm] are not provided for in this specification.

13.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the tube while the axis of the notch shall be perpendicular to the surface. On wall thickness of 1 in. [25 mm] or less, the specimens shall be obtained with their axial plane located at the midpoint; on wall thickness over 1 in. [25 mm], the specimens shall be obtained with their axial plane located ½ in [12.5 mm] from the outer surface.

13.3 When testing welds the specimen shall be, whenever diameter and thickness permits, transverse to the longitudinal axis of the tube with the notch of the specimen in the welded joint and perpendicular to the surface. When diameter and thickness does not permit obtaining transverse specimens, longitudinal specimens in accordance with 14.2 shall be obtained. The bottom of the notch shall be located at the weld joint.

14. Impact Test

14.1 Except when the size of the finished tube is insufficient to permit obtaining subsize impact specimens, all material furnished under this specification and marked in accordance with Section 15 shall be tested for impact resistance at the temperature for the respective grades as prescribed in Table 6.

14.1.1 Special impact tests on individual lots of material may be made at other temperatures if agreed upon between the manufacturer and the purchaser.

14.2 The notched-bar impact test shall be made in accordance with the procedure for the simple beam, Charpy-type of test of Methods E 23.

14.3 Impact tests specified for temperatures lower than +70°F [20°C] should be made with the following precautions. The impact test specimens as well as the handling tongs shall be cooled a sufficient time in a suitable container so that both reach the desired temperature. The temperature shall be measured with thermocouples, thermometers, or any other suitable devices and shall be controlled within ±3°F [2°C]. The specimens shall be quickly transferred from the cooling device to the anvil of the Charpy impact testing machine and broken with a time lapse of not more than 5 s. 98

14.4 When subsize Charpy impact specimens are used and the width along the notch is less than 80% of the actual wall thickness of the original material, the specified Charpy impact test temperature for Grades 1, 3, 6, 7, and 9 shall be lower than the minimum temperature shown in Table 6 for the respective grade. Under these circumstances the temperature reduction values shall be by an amount equal to the difference (as shown in Table 7) between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to Charpy specimen width actually tested. The appendix shows some examples of how the temperature reductions are determined.

15. Product Marking

15.1 Except as modified in 16.1.1, in addition to the marking prescribed in Specification A 450/A 450M, the marking shall include whether hot-finished, cold-drawn, seamless, or welded, and the letters "LT" followed by the temperature at which the impact tests were made, except when a lower test temperature is required because of reduced specimen size, in which case, the higher impact test temperature applicable to a full-size specimen should be marked.

15.1.1 When the size of the finished tube is insufficient to obtain subsize impact specimens, the marking shall not include the letters LT followed by an indicated test temperature unless Supplementary Requirement S1 is specified.

98

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %						
	Grade 1 [Note (1)]	Grade 3	Grade 6 [Note (1)]	Grade 7	Grade 8	Grade 9	Grade 11
Carbon, max	0.30	0.19	0.30	0.19	0.13	0.20	0.10
Manganese	0.40–1.06	0.31–0.64	0.29–1.06	0.90 max	0.90 max	0.40–1.06	0.60 max
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Silicon	...	0.18–0.37	0.10 min	0.13–0.32	0.13–0.32	...	0.35 max
Nickel	...	3.18–3.82	...	2.03–2.57	8.40–9.60	1.60–2.24	35.0–37.0
Chromium	...	...	...	...	...	...	0.50 max
Copper	...	...	...	...	...	0.75–1.25	...
Cobalt	...	...	...	...	...	...	0.50 max
Molybdenum	...	...	...	...	...	...	0.50 max

NOTE:
(1) For each reduction of 0.01% carbon below 0.30%, an increase of 0.05% manganese above 1.06% will be permitted to a maximum of 1.35% manganese.

TABLE 2
HEAT-TREATMENT LOT

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Under 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter, or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in thickness	not more than 75 tubes
1 in. [25.4 mm] or under in outside diameter	not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

	Grade 1		Grade 3		Grade 6		Grade 7		Grade 8		Grade 9		Grade 11	
	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
Tensile Strength, min	55	380	65	450	60	415	65	450	100	690	63	435	65	450
Yield Strength, min	30	205	35	240	35	240	35	240	75	520	46	315	35	240
Elongation in 2 in. or 50 mm (or 4*D*), min, %:														
Basic minimum elongation for walls $\frac{5}{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	35		30		30		30		22		28		18 [Note (1)]	
When standard round 2 in. or 50 mm gage length or proportionally smaller size specimen with the gage length equal to 4*D* (4 times the diameter) is used	28		22		22		22		16		...		...	
For strip tests, a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points	1.75 [Note (2)]		1.50 [Note (2)]		1.50 [Note (2)]		1.50 [Note (2)]		1.25 [Note (2)]		1.50 [Note (2)]		...	

Wall Thickness		Elongation in 2 in. or 50 mm, min % [Note (3)]					
in.	mm	Grade 1	Grade 3	Grade 6	Grade 7	Grade 8	Grade 9
$\frac{5}{16}$ (0.312)	8	35	30	30	30	22	28
$\frac{9}{32}$ (0.281)	7.2	33	28	28	28	21	26
$\frac{1}{4}$ (0.250)	6.4	32	27	27	27	20	25
$\frac{7}{32}$ (0.219)	5.6	30	26	26	26	18	24
$\frac{3}{16}$ (0.188)	4.8	28	24	24	24	17	22
$\frac{5}{32}$ (0.156)	4	26	22	22	22	16	20
$\frac{1}{8}$ (0.125)	3.2	25	21	21	21	15	19
$\frac{3}{32}$ (0.094)	2.4	23	20	20	20	13	18
$\frac{1}{16}$ (0.062)	1.6	21	18	18	18	12	16

Grade	Equation
1	$E = 56t + 17.50$ [$E = 2.19t + 17.50$]
3	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
6	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
7	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
8	$E = 40t + 9.50$ [$E = 1.56t + 9.50$]
9	$E = 48t + 13.00$ [$E = 1.87t + 13.00$]

where:
E = elongation in 2 in. or 50 mm, %, and
t = actual thickness of specimen, in. [mm].

GENERAL NOTE: The above table gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equations.

NOTES:
(1) Elongation of Grade 11 is for all walls and for small sizes tested in full section.
(2) The following table gives the calculated minimum values:
(3) Calculated elongation requirements shall be rounded to the nearest whole number.

TABLE 4
MAXIMUM HARDNESS NUMBER

Grade	Rockwell	Brinell
1	B 85	163
3	B 90	190
6	B 90	190
7	B 90	190
8	...	...
11	B 90	190

TABLE 5
IMPACT REQUIREMENTS FOR GRADES 1, 3, 6, 7, AND 9

Size of Specimen, mm	Minimum Average Notched Bar Impact Value of Each Set of Three Specimens [Note (1)]		Minimum Notched Bar Impact Value of One Specimen Only of a Set [Note (1)]	
	ft·lbf	J	ft·lbf	J
10 by 10	13	18	10	14
10 by 7.5	10	14	8	11
10 by 6.67	9	12	7	9
10 by 5	7	9	5	7
10 by 3.33	5	7	3	4
10 by 2.5	4	5	3	4

NOTE:
(1) Straight line interpolation for intermediate values is permitted.

TABLE 6
IMPACT TEMPERATURE

Grade	Impact Test Temperature °F	Impact Test Temperature °C
1	−50	−45
3	−150	−100
6	−50	−45
7	−100	−75
8	−320	−195
9	−100	−75

98

TABLE 7
IMPACT TEMPERATURE REDUCTION

Specimen Width Along Notch or Actual Material Thickness [Note (1)]		Temperature Reduction, Degrees Colder	
Inches	Millimetres	°F	°C
0.394	10 (standard size)	0	0
0.354	9	0	0
0.315	8	0	0
0.295	7.5 (3/4 standard size)	5	3
0.276	7	8	4
0.262	6.67 (2/3 standard size)	10	5
0.236	6	15	8
0.197	5 (1/2 standard size)	20	11
0.158	4	30	17
0.131	3.33 (1/3 standard size)	35	19
0.118	3	40	22
0.099	2.5 (1/4 standard size)	50	28

NOTE:
(1) Straight line interpolation for intermediate values is permitted.

SUPPLEMENTARY REQUIREMENT

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Nonstandard Test Specimens

S1.1 When the size of the finished tube is insufficient to permit obtaining subsize impact specimens, testing shall be a matter of agreement between the manufacturer and the purchaser.

APPENDIX

(Nonmandatory Information)

X1. DETERMINATION OF TEMPERATURE REDUCTIONS

X1.1 Under the circumstances stated in 14.4, the impact test temperatures specified in Table 6 must be lowered. The following examples are offered to described the application of the provisions of 14.4.

X1.1.1 When subsize specimens are used (see 13.1) and the width along the notch of the subsize specimen is 80% or greater of the actual wall thickness of the original material, the provisions of 14.4 do not apply.

X1.1.1.1 For example, if the actual wall thickness of pipe was 0.200 in. [5.0 mm] and the width along the notch of the largest subsize specimen obtainable is 0.160 in. [4 mm] or greater, no reduction in test temperature is required.

X1.1.2 When the width along the subsize specimen notch is less than 80% of the actual wall thickness of the pipe, the required reduction in test temperature is computed by taking the difference between the temperature reduction values shown in Table 7 for the actual pipe thickness and the specimen width used.

X1.1.2.1 For example, if the pipe were 0.262 in. [6.67 mm] thick and the width along the Charpy specimen notch was 3.33 mm ($\frac{1}{3}$ standard size), the test temperature would have to be lowered by 25°F [14°C] (that is, the temperature reduction corresponding to the subsize specimen is 35°F [19°C], the temperature reduction corresponding to the actual pipe thickness is 10°F [5°C]; the difference between these two values is the required reduction in test temperature).

STANDARD SPECIFICATION FOR SEAMLESS FERRITIC ALLOY-STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

SA-335/SA-335M

(Identical with ASTM Specification A 335/A 335M-95a.)

1. Scope

1.1 This specification covers nominal (average) wall seamless alloy-steel pipe intended for high-temperature service. Pipe ordered to this specification shall be suitable for bending, flanging (vanstoning), and similar forming operations, and for fusion welding. Selection will depend upon design, service conditions, mechanical properties, and high-temperature characteristics.

1.2 Several grades of ferritic steels (Note 1) are covered. Their compositions are given in Table 1.

NOTE 1 — Ferritic steels in this specification are defined as low- and intermediate-alloy steels containing up to and including 10% chromium.

1.3 Supplementary requirements (S1 to S7) of an optional nature are provided. These supplementary requirements call for additional tests to be made, and when desired, shall be so stated in the order together with the number of such tests required.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in noncomformace with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 2 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon Ferritic Alloy, and Austenitic Alloy Steel Tube

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

E 527 Practice for Numbering Alloys and Metals (UNS)

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *Other Documents:*

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification

SAE J 1086 Practice for Numbering Metals and Alloys (UNS)

3. General Requirements

3.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, centimetres, or number of lengths),

4.1.2 Name of material (seamless alloy steel pipe),

4.1.3 Grade (Table 1),

4.1.4 Manufacture (hot-finished or cold-drawn),

4.1.5 Size (NPS or outside diameter and schedule number or average wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish (Ends Section of Specification A 530/A 530M),

4.1.8 Optional requirements (Sections 7, 10, and 11, of this specification. See the Sections on Hydrostatic Test Requirements and Permissible Variation in Weight for Seamless Pipe in Specification A 530/A 530 M),

4.1.9 Test report required (Certification Section of Specification A 530/A 530M),

4.1.10 Specification designation, and

4.1.11 Special requirements or any supplementary requirements selected, or both.

5. Materials and Manufacture

5.1 Pipe may be either hot finished or cold drawn with the finishing treatment as required in 5.3.

5.2 *Grade P2 and P12* — The steel shall be made by coarse-grain melting practice. Specific limits, if any, on grain size or deoxidation practice shall be a matter of agreement between the manufacturer and purchaser.

5.3 *Heat Treatment:*

5.3.1 All pipe of grades shown in Table 1 except P5c, P91, and P92, and as provided in 5.3.2, shall be reheated and furnished in the full-annealed, isothermal annealed, or normalized and tempered condition. If furnished in the normalized and tempered condition, the minimum tempering temperature for Grades P5, P5b, P9, P21, and P22 shall be 1250°F [675°C], the minimum tempering temperature for Grades P1, P2, P11, P12, and P15 shall be 1200°F [650°C].

NOTE 3 — It is recommended that the temperature for tempering should be at least 100°F [50°C] above the intended service temperature; consequently, the purchaser should advise the manufacturer if the service temperature is to be over 1100°F [600°C].

5.3.2 Pipe of Grades P1, P2, and P12, either hot finished or cold drawn, may be given a final heat treatment at 1200°F [650°C] to 1300°F [705°C] instead of heat treatments specified in 5.3.1.

5.3.3 All pipe of Grades P5c shall be given a final heat treatment in the range from 1325°F [715°C] to 1375°F [745°C].

NOTE 4 — Certain of the ferritic steels covered by this specification will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures. Therefore, operations involving heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

5.3.4 Grade T92 shall be normalized at 1900°F [1040°C] minimum and tempered at 1350°F [730°C] minimum is a final heat treatment.

5.4 Except when Supplementary Requirement S7 is specified by the purchaser, Grade P91 shall be normalized at 1900°F [1040°C] minimum, and tempered at 1350°F [730°C] minimum as a final heat treatment. Alternatively, liquid quenching and tempering is allowed for thicknesses above 3 in. when mutually agreed upon between the manufacturer and the purchaser. In this case the pipe shall be quenched from 1900°F [1040°C] minimum and tempered at 1350°F [730°C] minimum as final heat treatment.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Product Analysis

7.1 At the request of the purchaser, an analysis of two pipes from each lot shall be made by the manufacturer. A lot (Note 5) of pipe shall consist of the following:

NPS Designator	
Under 2	400 or fraction thereof
2 to 5	200 or fraction thereof
6 and over	100 or fraction thereof

NOTE 5 — A lot shall consist of the number of lengths specified in 7.1 of the same size and wall thickness from any one heat of steel.

7.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Table 1.

7.3 For grade P91 the carbon content may vary for the product analysis by −0.01% and +0.02% from the specified range as per Table 1.

7.4 If the analysis of one of the tests specified in 7.1 does not conform to the requirements specified in 6.1, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

8. Tensile Requirements

8.1 The tensile properties of the material shall conform to the requirements prescribed in Table 2.

9. Workmanship, Finish, and Appearance

9.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to ensure compliance with 10.2.

9.2 Surface imperfections that penetrate more than $12\frac{1}{2}$% of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

9.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

9.2.2 Repaired in accordance with the repair welding provisions of 9.6.

9.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

9.2.4 Rejected.

9.3 To provide a workmanlike finish and basis for evaluating conformance with 9.2, the pipe manufacturer shall remove by grinding the following:

9.3.1 Mechanical marks, abrasions (Note 6) and pits, any of which are deeper than $\frac{1}{16}$ in. [1.6 mm].

NOTE 6 — Marks and abrasions are defined as cable marks, dings, guide marks, roll marks, ball scratches, scores, die marks, and the like.

9.3.2 Visual imperfections, commonly referred to as scabs, seams, laps, tears, or slivers, found by exploration in accordance with 9.1 to be deeper than 5% of the nominal wall thickness.

9.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 9.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

9.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

9.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

9.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

9.7 The finished pipe shall be reasonably straight.

10. Hydrostatic Test

10.1 Each length of pipe shall be subjected to the hydrostatic test, except as provided for in 10.2 or 10.3.

10.2 When specified by the purchaser, pipe shall be tested by a nondestructive examination method in lieu of the hydrostatic test as shown in Section 11.

10.3 When specified by the purchaser, pipe shall be furnished without hydrostatic test and without nondestructive examination.

10.4 When specified by the purchaser, pipe shall be furnished with both the hydrostatic test and a nondestructive examination having been performed.

11 Nondestructive Examination

11.1 When specified by the purchaser, as an alternative to the hydrostatic test (10.2), or in addition to the hydrostatic test (10.4), each pipe shall be examined by a nondestructive examination method in accordance with Practice E 213, Practice E 309, or Practice E 570. The range of pipe sizes that may be examined

by each method shall be subject to the limitations in the scope of the respective practices.

11.2 The following information is for the benefit of the user of this specification:

11.2.1 The reference standards defined in 11.8 are convenient standards for standardization of nondestructive examination equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

11.2.2 Ultrasonic examination can be performed to detect both longitudinally and transversely oriented discontinuities. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep imperfections.

11.2.3 The eddy current examination referenced in this specification has the capability to detect significant discontinuities, especially of the short abrupt type.

11.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

11.2.5 The hydrostatic test of Section 10 has the capability to find imperfections of a size that permit the test fluid to leak through the pipe wall so that it may be either visually seen or detected by a loss of fluid pressure. This test may not detect very tight, through-wall imperfections, or imperfections that extend into the wall without complete penetration.

11.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular products.

11.3 *Time of Examination* — Nondestructive examination for specification acceptance shall be performed after all mechanical processing, heat treatments and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

11.4 *Surface Conditions:*

11.4.1 All surfaces shall be clean and free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

11.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test (see 11.10.2.3).

11.5 *Extent of Examination:*

11.5.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except for end effects as noted in 11.5.2.

11.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

11.6 *Operator Qualifications* — The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent, recognized, and documented standard.

11.7 *Test Conditions:*

11.7.1 For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.25 MHz.

11.7.2 For eddy current testing, the excitation coil frequency shall be 10 kHz, or less.

11.8 *Reference Standards:*

11.8.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS or outside diameter and schedule or wall thickness), surface finish, and heat treatment condition as the pipe to be examined.

11.8.2 For ultrasonic testing, the reference notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of the notch shall not exceed 12½% of the specified nominal wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater. The length of the notch shall be at least twice the diameter of the transducer(s). The width of the notch shall not exceed the depth.

11.8.3 For eddy current testing, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

11.8.3.1 *Drilled Hole* — The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated

by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
½	0.039 in. [1 mm]
above ½ to 1¼	0.055 in. [1.4 mm]
above 1¼ to 2	0.071 in. [1.8 mm]
above 2 to 5	0.087 in. [2.2 mm]
above 5	0.106 in. [2.7 mm]

11.8.3.2 *Transverse Tangential Notch* — Using a round tool or file with a ¼ in. [6.4 mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12½% of the specified nominal wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater.

11.8.3.3 *Longitudinal Notch* — A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12½% of the specified nominal wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

11.8.4 For flux leakage testing, the longitudinal reference notches shall be straight-sided notches machined in a radial plane parallel to the pipe axis. For wall thickness less than ½ in. [12.7 mm], outside and inside notches shall be used; for wall thicknesses equal to or greater than ½ in., only an outside notch shall be used. Notch depth shall not exceed 12½% of the specified nominal wall thickness or 0.004 in. [0.1 mm], whichever is greater. Notch length shall not exceed 1 in. [25.4 mm], and the width shall not exceed the depth. Outside and inside notches shall have sufficient separation to allow distinct identification of the signal from each notch.

11.8.5 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

11.9 *Standardization Procedure:*

11.9.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h during the examination of such pipe. More frequent standardizations may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

11.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, shutdown, or operator breaks.

11.9.3 The reference standard shall be passed through the test apparatus at same speed and test system settings as the pipe to be tested.

11.9.4 The signal-to-noise ratio for the reference standard shall be 2.5 to 1 or greater and the reference signal amplitude for each discontinuity shall be at least 50% of full scale of the display.

11.9.5 If upon any standardization, the reference signal amplitude as decreased by 25% (2 db), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization must be retested.

11.10 *Evaluation of Imperfections:*

11.10.1 Pipes producing a signal equal to or greater than the signal produced by the reference standard shall be positively identified and they shall be separated from the acceptable pipes. The area producing the signal may be reexamined.

11.10.2 Such pipes shall be subject to one of the following three dispositions:

11.10.2.1 The pipes may be rejected without further examination, at the discretion of the manufacturer.

11.10.2.2 The pipes shall be rejected, but may be repaired, if the test signal was produced by imperfections which cannot be identified, or was produced by cracks or crack-like imperfections. These pipes may be repaired by grinding (in accordance with 9.2.1), welding (in accordance with 9.6), or sectioning (in accordance with 9.2.3). To be accepted, a repaired pipe must pass the same nondestructive examination by which it was rejected, and it must meet the remaining wall thickness requirements of this specification.

11.10.2.3 Such pipes may be evaluated in accordance with the provisions of Section 9, if the test signals were produced by visual imperfections such as those listed below:

(a) Scratches,
(b) Surface roughness,
(c) Dings,
(d) Straightener marks,
(e) Cutting chips,
(f) Steel die stamps,
(g) Stop marks, or
(h) Pipe reducer ripple.

12. Mechanical Tests Required

12.1 *Transverse or Longitudinal Tension Test and Flattening Test, or Bend Test* — For material heat treated in a batch-type furnace, tests shall be made on 5% of the pipe from each treated lot (Note 7). For small lots, at least 1 pipe shall be tested. For material heat treated by the continuous process, tests shall be made on a sufficient number of pipe to constitute 5% of the lot (Note 7), but in no case less than 2 pipe.

NOTE 7 — The term "lot" applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace; when final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge.

12.2 *Bend Test:*

12.2.1 For pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less shall be subjected to the bend test instead of the flattening test. Other pipe whose diameter equals or exceeds NPS 10 may be given the bend test in place of the flattening test subject to the approval of the purchaser.

12.2.2 The bend test specimens shall be bent at room temperature through 180°F without cracking on the outside of the bent portion. The inside diameter of the bend shall be 1 in. [25 mm].

12.2.3 Test specimens for the bend test specified in 12.2 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either ½ by ½ in. [12.5 by 12.5 mm] in section or 1 by ½ in. [25 by 12.5 mm] in section with the corners rounded to a radius not over 1/16 in. [1.6 mm] and need not exceed 6 in. [150 mm] in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe, respectively.

13. Certification

13.1 In addition to the information required by Specification A 530/A 530M, the certification shall state whether or not the material was hydrostatically tested. If the material was nondestructively examined, the certification shall so state and shall show which practice was followed and what reference discontinuities were used. In addition, the test method information as given in Table 3 shall be appended to the specification number and grade shown on the certification.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include the length, an additional symbol "S", if the pipe conforms to any of the Supplementary Requirements S1 to S6, the ANSI schedule number, and the heat number or manufacturer's number by which the heat can be identified. Furthermore, the marking designated in Table 3 to indicate the test method(s) shall be included. Marking may be by stenciling, stamping, or rolling. Pipe that has been weld repaired in accordance with 9.6 shall be marked "WR."

15. Government Procurement

15.1 *Scale Free Pipe:*

15.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale free pipe or tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

15.1.2 The requirements of Specification A 530/A 530M for pipe and Specification A 450/A 450M for tubes shall be applicable when pipe or tube is ordered to this specification.

15.1.3 Pipe and tube shall be one of the following grades as specified herein:

Grade	UNS Designation
P11	K11597
P22	K21590
P5	K41545

15.1.4 *Part Number:*

15.1.4.1 Pipe shall be ordered to nominal pipe size and schedule specified in ANSI B36.10.

Example: A335/A 335M Pipe P-11 NPS 12 Sch 40

Specification Number	ASTM A 335/A 335M
Pipe	P
Grade	P-11
NPS	12
Wall	0.375

15.1.4.2

Specification Number	ASTM A 335/A 335M
Tube	T
Grade	P-11
Outside Diameter	0.250
Wall	0.035

15.1.5 *Ordering Information* — Orders for material under this specification shall include the following in addition to the requirements of Section 3:

15.1.5.1 Pipe or tube,

15.1.5.2 Part number,

15.1.5.3 Ultrasonic inspection, if required,

15.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions, and

15.1.5.5 Level of preservation and packing required.

16. Keywords

16.1 alloy steel pipe; high temperature service; seamless steel pipe; steel pipe; temperature service applications, high

TABLE 1
CHEMICAL REQUIREMENTS

Grade	UNS Designation [Note (1)]	Composition, %							
		Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Others
P1	K11522	0.10–0.20	0.30–0.80	0.025	0.025	0.10–0.50	...	0.44–0.65	...
P2	K11547	0.10–0.20	0.30–0.61	0.025	0.025	0.10–0.30	0.50–0.81	0.44–0.65	...
P5	K41545	0.15 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	...
P5b	K51545	0.15 max	0.30–0.60	0.025	0.025	1.00–2.00	4.00–6.00	0.45–0.65	...
P5c	K41245	0.12 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	... [Note (2)]
P9	S50400	0.15 max	0.30–0.60	0.025	0.025	0.25–1.00	8.00–10.00	0.90–1.10	...
P11	K11597	0.05–0.15	0.30–0.60	0.025	0.025	0.50–1.00	1.00–1.50	0.44–0.65	...
P12	K11562	0.05–0.15	0.30–0.61	0.025	0.025	0.50 max	0.80–1.25	0.44–0.65	...
P15	K11578	0.05–0.15	0.30–0.60	0.025	0.025	1.15–1.65	...	0.44–0.65	...
P21	K31545	0.05–0.15	0.30–0.60	0.025	0.025	0.50 max	2.65–3.35	0.80–1.06	...
P22	K21590	0.05–0.15	0.30–0.60	0.025	0.025	0.50 max	1.90–2.60	0.87–1.13	...
P91	K91560	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.00–9.50	0.85–1.05	V 0.18–0.25 N 0.030–0.070 Ni 0.40 max Al 0.04 max Cb 0.06–0.10
T92	K92460	0.07–0.13	0.30–0.60	0.020	0.010	0.50 max	8.50–9.50	0.30–0.60	V 0.15–0.25 N 0.03–0.07 Ni 0.40 max Al 0.04 max Cb 0.04–0.09 W 1.5–2.00 B 0.001–0.006

NOTES:
(1) New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).
(2) Grade P5c shall have a titanium content of not less than 4 times the carbon content and not more than 0.70%; or a columbium content of 8 to 10 times the carbon content.

TABLE 2
TENSILE REQUIREMENTS

Identification Symbol	P1, P2	P12	P91	P92	All Others
Tensile strength, min:					
ksi	55	60	85	90	60
MPa	380	415	585	620	415
Yield strength, min:					
ksi	30	32	60	64	30
MPa	205	220	415	440	205

	Elongation Requirements, All grades except P91 and P92		P91	
	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. or 50 mm, (or 4*D*), min, %:				
Basic minimum elongation for wall $^{5}/_{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	30	20	20	...
When standard round 2-in. or 50-mm gage length or proportionally smaller size specimen with the gage length equal to 4*D* (4 times the diameter) is used	22	14	20	13
For strip tests a deduction for each $^{1}/_{32}$-in. [0.8 mm] decrease in wall thickness below $^{5}/_{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points shall be made	1.50 [Note (1)]	1.00 [Note (1)]	1.00 [Note (1)]	...

[A]The following table gives the calculated minimum values:

Wall Thickness		Elongation in 2 in. or 50 mm, min, %		
		All grades except P91 and P92		P91 and P92
in.	mm	Longitudinal	Transverse	Longitudinal
$^{5}/_{16}$ (0.312)	8	30	20.0	20
$^{9}/_{32}$ (0.281)	7.2	29	19.0	19
$^{1}/_{4}$ (0.250)	6.4	27	18.0	18
$^{7}/_{32}$ (0.219)	5.6	26	...	17
$^{3}/_{16}$ (0.188)	4.8	24	...	16
$^{5}/_{32}$ (0.156)	4	22	...	15
$^{1}/_{8}$ (0.125)	3.2	21	...	14
$^{3}/_{32}$ (0.094)	2.4	20	...	13
$^{1}/_{16}$ (0.062)	1.6	18	...	12

GENERAL NOTE: This table gives the computed minimum elongation values for each $^{1}/_{32}$-in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values above, the minimum elongation value is determined by the following formula:

Direction of Test	Equation [Note (2)]
Longitudinal, all grades except P91	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
Transverse	$E = 32t + 10.00$ [$E = 1.25t + 10.00$]
Longitudinal, P91	$E = 32t + 10.00$ [$E = 1.25t + 10.00$]

TABLE 3
TEST METHOD INFORMATION FOR CERTIFICATION AND MARKING

Hydrostatic	Nondestructive	Marking
YES	NO	Test Pressure
NO	YES	NDE
NO	NO	NH
YES	YES	Test Pressure/NDE

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound. The bend test of 12.2 shall be substituted for the flattening test for pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less.

S4. Metal Structure and Etching Tests

S4.1 The steel shall be homogenous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

NOTE 8 — Pending development of etching methods applicable to the product covered by this specification, it is recommended that the Recomended Practice for a Standard Macro Etch Test for Routine Inspection of Iron and Steel, described in the *Metals Handbook,* Am. Soc. for Metals, 1948 edition, p. 389, be followed.

S5. Photomicrographs

S5.1 When requested by the purchaser and so stated in the order, the manufacturer shall furnish one photomicrograph at 100 diameters from a specimen of pipe in the as-finished condition for each individual size and wall thickness from each heat, for pipe NPS 3 and over. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S6. Such photomicrographs are for information only, to show the actual metal structure of the pipe as finished.

S6. Photomicrographs for Individual Pieces

S6.1 In addition to the photomicrographs required in accordance with Supplementary Requirement S5, the purchaser may specify that photomicrographs shall be

furnished from each end of one or more pipes from each lot of pipe NPS 3 and larger in the as-finished condition. The purchaser shall state in the order the number of pipes to be tested from each lot. When photomicrographs are required on each length, the photomicrographs from each lot of pipe in the as-finished condition which may be required under Supplementary Requirement S5 may be omitted. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S7. Alternative Heat Treatment — Grade P91

S7.1 Grade P91 shall be normalized in accordance with 5.3 and tempered at a temperature, to be specified by the purchaser, less than 1350°F [730°C]. It shall be purchaser's responsibility to subsequently temper at 1350°F [730°C] minimum. All mechanical tests shall be made on material heat treated in accordance with 5.3. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S7" shall be included with the required marking of the pipe.

SPECIFICATION FOR ALLOY STEEL FORGINGS FOR PRESSURE AND HIGH-TEMPERATURE PARTS

SA-336/SA-336M

(Identical with ASTM Specification A 336/A 336M-96 except for clarified heat treatment requirements in 6.2.) 98

1. Scope

1.1 This specification covers both ferritic and austenitic steel forgings for boilers, pressure vessels, high-temperature parts, and associated equipment.

1.2 Forgings made of steel grades listed in Specification A 335/A 335M, may also be ordered under this specification. The chemical, tensile, heat treatment, and marking requirements of Specification A 335/A 335M shall apply, except the forging shall conform to the chemical requirements of Table 1 of Specification A 335/A 335M only with respect to heat analysis. On check analysis they may deviate from these limits to the extent permitted in Table 2 of this specification.

NOTE 1 — For all austenitic steels, the term "Class" has been changed to "Grade."

Current	Formerly
Grade F1	Class F1
Grade F11, Class 2	Class F11
Grade F11, Class 3	Class F11A
Grade F11, Class 1	Class F11B
Grade F12	Class F12
Grade F5	Class F5
Grade F5A	Class F5A
Grade F9	Class F9
Grade F6	Class F6
Grade F21, Class 1	Class F21A
Grade F21, Class 3	Class F21
Grade F22, Class 1	Class F22A
Grade F22, Class 3	Class F22
Grade F91	Class F91
Grade F3V	Class F3V
Grade F22V	Class F22V

1.3 Supplementary Requirements S1 to S9 are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standards. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 335/A 335M Specification for Seamless Ferritic Alloy Steel Pipe for High-Temperature Service

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 788 Specification for Steel Forgings, General Requirements

E 112 Test Methods for Determining Average Grain Size

E 165 Test Method for Liquid Penetrant Examination

2.2 *Other Standard:*

ASME Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, the purchaser should include with the inquiry and order the following information:

3.1.1 A drawing or sketch that shows test locations when the testing is in accordance with 8.1.1.3.

3.1.2 The intended use of forgings if 5.1 is applicable.

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

4. Melting and Forging

4.1 In addition to the melting and forging requirements of Specification A 788 which may be supplemented by Supplementary Requirement S8, the following conditions apply:

4.1.1 Austenitic grades of steel shall not be produced by the open-hearth process.

4.1.2 A sufficient discard shall be made to secure freedom from injurious pipe and undue segregation.

NOTE 2 — Because of difficulties in retaining nitrogen, vacuum melting or remelting processes should not be specified for Grades F304N, F304LN, F316N, F316LN and FXM-11.

5. Machining

5.1 Forged pressure vessels for steam power service shall have the inner surface machined or ground. Unfired pressure vessels shall have the inner surfaces sufficiently free of scale to permit inspection.

5.2 When rough machining is performed, it may be done either before or after heat treatment.

6. Heat Treatment

6.1 The ferritic steel forgings shall be annealed or normalized and tempered but alternatively may be liquid quenched and tempered when mutually agreed upon between the manufacturer and the purchaser. Grade F22V forgings shall be normalized and tempered or liquid quenched and tempered. For Grade F22V forgings the minimum austenizing temperature shall be 1650°F [900°C]. For Grade F91 forgings the normalizing temperature shall be in the range of 1900 to 2000°F [1040 to 1095°C]. Normalizing or liquid quenching shall be followed by tempering at a subcritical temperature. Minimum tempering temperature shall be 1100°F [595°C], except for the following grades:

Grade	Minimum Tempering Temperature, °F [°C]
F6	1150 [620]
F11, Class 2	1150 [620]
F11, Class 3	1150 [620]
F11, Class 1	1150 [620]
F5	1250 [675]
F9	1250 [675]
F21, Class 1	1250 [675]
F3V, F3VCb	1250 [675]
F22, Class 1	1250 [675]
F22V	1250 [675]
F91	1350 [730]

6.2 For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments.

6.2.1 Grade FXM-11 and FXM-19 shall be solution annealed at 1950 ± 25°F [1065 ± 15°C].

6.2.2 Grade F46 shall be solution annealed at temperatures in the range 2010–2140°F [1100–1170°C] followed by water quenching or other means of rapid cooling.

7. Chemical Composition

7.1 *Heat Analysis* — The heat analysis obtained from sampling in accordance with Specification A 788 and shall comply with Table 1.

7.2 *Product Analysis* — The manufacturer shall use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat. The product analysis for columbium and calcium for Grade F22V shall conform to the requirements of Table 1 of this specification. Boron is not subject to product analysis. The purchaser may also make this determination in accordance with Specification A 788.

8. Mechanical Properties

8.1 *General Requirements* — The material shall conform to the requirements for mechanical properties prescribed in Table 2. The largest obtainable tension test specimen as specified in Test Methods and Definitions A 370 shall be used.

8.1.1 For annealed, normalized, and tempered ferritic steels not tested per 8.1.1.3 and austenitic steels, the longitudinal axis of the specimens shall be parallel to the direction of major working of the forging, except when Supplementary Requirement S2 is specified. For upset disk forgings, the longitudinal axis of the test specimen shall be in the tangential direction.

8.1.1.1 The longitudinal axis of the specimen shall be located midway between the parallel surfaces of the test extension if added to the periphery of disks or midway between the center and surface of solid forgings. For hollow forgings, the longitudinal axis of the specimens shall be located midway between the center and outer surfaces of the wall. When separately forged test blocks are employed, as defined in 8.1.3, the tension test specimens shall be taken from a location which represents the midwall of the heaviest section of the production forgings. When specimens are required from opposite ends, they shall be taken from the diagonal corners of an axial plane. Alternatively, and when specified, the specimens shall be taken in accordance with Supplementary Requirement S3.

8.1.1.2 For liquid quenched and tempered ferritic steel forgings, the test specimens shall have their longitudinal axis at least $\frac{1}{4}T$ of the maximum heat-treated thickness from any surface and with the mid-length of the specimens at least one T from any second surface. This is normally referred to as $\frac{1}{4}T \times T$, where T is the maximum heat-treated thickness. A thermal buffer may be used to adhere to the above condition.

8.1.1.3 For normalized and tempered and liquid quenched and tempered ferritic steel forgings. With prior purchaser approval, test specimens may be taken at a depth (t) corresponding to the distance from the area of significant stress to the nearest heat-treated surface and at least twice this distance ($2\ t$) from any second surface. However, the test depth shall not be nearer to one heat-treated surface than $\frac{3}{4}$in. [19 mm] and to the second treated surface than $1\frac{1}{2}$in. [38 mm]. This method of test specimen location normally applies to thick and complex pressure vessel components where the testing in 8.1.1.2 is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

8.1.2 Except as specified herein, tests for acceptance shall be made after heat treatment has been completed in accordance with Section 6. When the ends of the cylindrical forgings are closed in by reforging, the cylindrical forgings may be normalized and tempered or annealed and tested before reforging. After reforging, the entire forging shall be reheat-treated in the same manner and at the same temperature range as employed when the forging was heat-treated before certification testing.

8.1.3 When mutually agreed upon between the manufacturer and the purchaser, test specimens may be machined from a specially forged block suitably worked and heat treated with the production forgings. Such a special block shall be obtained from an ingot, slab, or billet from the same heat used to make the forgings it represents. This block shall receive essentially the same type of hot-working and forging reduction as the production forgings; however, a longitudinally forged bar with dimensions not less than T by T by $3T$ may be used to represent a ring forging. The dimension T shall be representative of the heaviest effective cross section of the forging. For quenched and tempered forgings for which tests are required at both ends by 8.2.2.3 and 8.2.2.4, separately forged test blocks are not allowed.

NOTE 3 — In using separately forged test blocks attention is drawn to the effect of mass differences between the production forgings and the test blocks. This can be particularly significant for the ferritic grades when forgings are normalized and tempered or quenched and tempered.

8.2 *Number and Location of Tests* — The number and location of tests are based on forging length, weight, and heat treatment and shall be as prescribed below. The length and weight to be used for this purpose shall be the shipped length and weight of forgings produced individually or the aggregate shipped length and weight of all pieces cut from a multiple forging.

8.2.1 *Annealed or Normalized and Tempered Alloy Steel Forgings:*

8.2.1.1 For forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, one tension test shall be taken from one forging per heat, per heat treatment charge. When heat treatment is performed in continuous type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8 h period.

8.2.1.2 For forgings and forged bars weighing over 5000 lb [2250 kg] at the time of heat treatment, one tension test shall be taken from each forging.

8.2.2 *Quenched and Tempered Forgings:*

8.2.2.1 For quenched and tempered forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from one forging per heat, per heat treatment charge. When heat treatment is performed in continuous type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8 h period.

8.2.2.2 For quenched and tempered forgings and forged bars weighing over 5000 to 10 000 lb [2250 to 4500 kg] at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from each forging.

8.2.2.3 Quenched and tempered forgings that exceed 12 ft [3.7 m] in length shall be tension tested at both ends of the forging under test.

98 **8.2.2.4** For quenched and tempered forgings and forged bars weighing more than 10 000 lb [4500 kg] at the time of heat treatment, two tension tests shall be taken from each forging. These shall be offset 180° from each other except that if the length of the forging, excluding test prolongations, exceeds 12 ft [3.7 m], then one specimen shall be taken from each end of the forging.

8.3 *Notch Toughness Requirements — Grades F3V, F3VCb, and F22V:*

8.3.1 Impact test specimens shall be charpy V-notch Type A, as shown in Fig. 11 of Test Methods and Definitions A 370. The usage of subsize specimens due to material limitations must have prior purchaser approval.

8.3.2 The charpy V-notch test specimens shall be obtained as required for tension tests in 8.1 and 8.2. One set of three charpy V-notch specimens shall be taken from each tensile specimen location.

8.3.3 The longitudinal axis and mid-length of impact specimen shall be located similarly to the longitudinal axis of the tension test specimens. The axis of the notch shall be normal to the nearest heat treated surface of the forging.

8.3.4 The charpy V-notch tests shall meet a minimum energy absorption value of 40 ft · lbf [54 J] average of three specimens. One specimen only in one set may be below 40 ft · lbf [54 J] and it shall meet a minimum value of 35 ft · lbf [48 J].

8.3.5 The impact test temperature shall be 0°F [−18°C].

9. Grain Size

9.1 For Grades F304H, F316H, F309H, F310H, F321H, F347H and F348H, the grain size of the forgings shall be ascertained according to Test Methods E 112, after solution treatment. One sample shall be examined for each tensile specimen required in 8.2, and shall be taken from the tension test location. The grain size shall be number 6, or coarser over at least 75% of the surveyed area.

10. Workmanship, Finish, and Appearance

10.1 When ferritic forgings have been heat treated by quenching and tempering, all accessible surfaces shall subsequently be examined for quench cracks by the magnetic particle method in accordance with Test Method A 275/A 275M.

11. Repair Welding

11.1 Repair welding of forgings may be permitted but only at the option of the purchaser. Such repair welds shall be made in accordance with Section IX of the ASME Boiler & Pressure Vessel Code.

12. Marking

12.1 In addition to the marking requirements of Specification A 788, the specification marking shall be followed by the letter A for annealed, N for normalized and tempered or Q for liquid quenched and tempered as applicable.

13. Test Reports

13.1 The certification requirements of Specification A 788 shall apply.

14. Keywords

14.1 austenitic stainless steel; chromium alloy steel; chromium-molybdenum steel; pressure containing parts; pressure vessel service; stainless steel forgings; steel forgings; steel forgings — alloy; temperature service applications — high

TABLE 1
CHEMICAL REQUIREMENTS

Composition, %								
Ferritic Steels								
Grade								
Element	F1	F11, Classes 2 and 3	F11, Class 1	F12	F5 [Note (1)]	F5A [Note (1)]	F9	F6
Carbon	0.20–0.30	0.10–0.20	0.05–0.15	0.10–0.20	0.15 max	0.25 max	0.15 max	0.12 max
Manganese	0.60–0.80	0.30–0.80	0.30–0.60	0.30–0.80	0.30–0.60	0.60 max	0.30–0.60	1.00 max
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Silicon	0.20–0.35	0.50–1.00	0.50–1.00	0.10–0.60	0.50 max	0.50 max	0.50–1.00	1.00 max
Nickel	. . .	. . .	. . .	. . .	0.50 max	0.50 max	. . .	0.50 max
Chromium	. . .	1.00–1.50	1.00–1.50	0.80–1.10	4.0–6.0	4.0–6.0	8.0–10.0	11.5–13.5
Molybdenum	0.40–0.60	0.45–0.65	0.44–0.65	0.45–0.65	0.45–0.65	0.45–0.65	0.90–1.10	. . .

Grade		
Element	F21, Classes 1 and 3	F22, Classes 1 and 3
Carbon	0.05–0.15	0.05–0.15
Manganese	0.30–0.60	0.30–0.60
Phosphorus, max	0.025	0.025
Sulfur, max	0.025	0.025
Silicon	0.50 max	0.50 max
Nickel	. . .	. . .
Chromium	2.7–3.3	2.00–2.50
Molybdenum	0.80–1.06	0.90–1.10
Vanadium	. . .	. . .
Copper	. . .	. . .
Nitrogen	. . .	. . .
Columbium	. . .	. . .

Element	Grade F91	F3V	F3VCb	F22V
Carbon	0.08–0.12	0.10–0.15	0.10–0.15	0.11–0.15
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60
Phosphorus, max	0.025	0.020	0.020	0.015
Sulfur, max	0.025	0.020	0.010	0.010
Silicon	0.20–0.50	0.10 max	0.10 max	0.10 max
Nickel	0.40 max	. . .	0.25 max	0.25 max
Chromium	8.0–9.5	2.7–3.3	2.7–3.3	2.00–2.50
Molybdenum	0.85–1.05	0.90–1.10	0.90–1.10	0.90–1.10
Vanadium	0.18–0.25	0.20–0.30	0.20–0.30	0.25–0.35
Columbium	0.06–0.10	. . .	0.015–0.070	0.07 max
Nitrogen	0.03–0.07	. . .	. . .	. . .
Aluminum	0.04 max	. . .	. . .	. . .
Boron	. . .	0.001–0.003	. . .	0.0020 max
Titanium	. . .	0.015–0.035	0.015 max	0.030 max
Copper	. . .	. . .	0.25 max	0.20 max
Calcium	. . .	. . .	0.0005–0.0150	0.015 max [Note (6)]

TABLE 1 (CONT'D)
CHEMICAL REQUIREMENTS

	Austenitic Steels																					
	Grade																					
Element	F 304	F 304H	F 304L	F 304N	F 304LN	F 309H	F 310	F 310H	F 316	F 316H	F 316L	F 316N	F 316LN	F 321	F 321H	F 347	F 347H	F 348	F 348H	FXM-19	FXM-11	F46
Carbon	0.08 max	0.04–0.10	0.035 max	0.08 max	0.030 max	0.04–0.10	0.15 max	0.04–0.10	0.08 max	0.04 to 0.10	0.035 max	0.08 max	0.030	0.08 max	0.04–0.10	0.08 max	0.04–0.10	0.08 max	0.04–0.10	0.06 max	0.04 max	0.018 max
Manganese	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00	2.00 max	2.00	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.50 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	4.0–6.0	8.0–10.0	2.00 max
Phosphorus, max	0.040	0.045	0.040	0.030	0.040	0.040	0.040	0.040	0.040	0.045	0.040	0.030	0.040	0.035	0.040	0.040	0.040	0.40	0.040	0.040	0.060	0.020
Sulfur, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.30	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.020
Silicon, max	1.00	1.00	1.00 max	0.75	1.00	1.00	1.00	1.50	1.00	1.00	1.00 max	0.75	1.00	0.85	1.00 max	0.85	1.00 max	1.00 max	1.00 max	1.00 max	1.00	3.7–4.3
Nickel	8.0–11.0	8.0–12.0	8.0–13.0	8.0–11.0	8.0–11.0	12.0–15.0	19.0–22.0	19.00–22.00	10.0–14.0	10.0–14.0	10.0–15.0	11.0–14.0	10.0–14.0	9.0 min	9.0–12.0	9.0–12.0	9.0–13.0	9.0–13.0	9.0–13.0	11.5–13.5	5.5–7.5	14.0–15.5
Chromium	18.0–20.0	19.0–20.0	18.0–20.0	18.0–20.0	18.0–20.0	22.0–24.0	24.0–26.0	24.00–26.00	16.0–18.0	16.0–18.0	16.0–18.0	16.0–18.0	16.0–18.0	17.0 min	17.0 min	17.0–19.0	17.0–20.0	17.0–20.0	17.0–20.0	20.5–23.5	19.0–21.5	17.0–18.5
Molybdenum	...	...	...	...	...	...	...	...	2.00–3.00	2.00–3.00	2.00–3.00	2.00–3.00	2.00–3.00	...	...	...	...	...	...	1.50–3.00	...	0.20 max
Nitrogen	...	...	...	0.10–0.16	0.10–0.16	...	...	...	...	...	...	0.10–0.16	0.10–0.16	...	...	...	...	...	...	0.20–0.40	0.15–0.40	...
Columbium and Tantalum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	[Note (2)]	8×C min to 1.00 max	10 × C min to 1.00 max	8 × C min to 1.00 max	0.10–0.30	...	...
Titanium	...	...	...	...	...	...	...	...	...	...	...	...	...	[Note (3)]	4 × C min to 0.60 max	...	...	...	...	...	...	...
Tantalum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.10 max	0.10 max	...	...	...
Vanadium	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.10–0.30	...	...

NOTES:
(1) The present Grade F5A (0.25 %, maximum carbon) previous to 1955 was assigned the identification symbol F5. Identification symbol F5 has been assigned to the 0.15%, maximum, carbon grade to be consistent with ASTM specifications for other products such as pipe, tubing, bolting, welding, fittings, etc.
(2) F347 shall have a columbium content of not less than ten times the carbon content and not more than 1.00%. (Alternately, tantalum may be substituted for part of the columbium as approved.)
(3) F321 shall have a titanium content of not less than five times the carbon content and not more than 0.60%.
(4) Nickel plus copper.
(5) For small diameter (less than 0.500 in. [12.5 mm] or thin walls (less than 0.40 in. [10 mm] minimum specified wall thickness) tubes, a carbon maximum of 0.015% is permitted.
(6) For Grade F22V, rare earth metals (REM) may be added in place of calcium subject to agreement between the producer and the purchaser. In that case the total amount of REM shall be determined and reported.

TABLE 2
TENSILE REQUIREMENTS

	Ferritic Steels																
	Grade																
	F1	F11, Class 2	F11, Class 3	F11, Class 1	F12	F5	F5A	F9	F6	F21, Class 3	F21, Class 1	F22, Class 3	F22, Class 1	F91	F3V	F3VCb	F22V
Tensile strength, psi [MPa]	70,000–95,000 [485–660]	70,000–95,000 [485–660]	75,000–100,000 [515–690]	60,000–85,000 [415–585]	70,000–95,000 [485–660]	60,000–85,000 [415–585]	80,000–105,000 [550–725]	85,000–110,000 [585–760]	85,000–110,000 [585–760]	75,000–100,000 [515–690]	60,000–85,000 [415–585]	75,000–100,000 [515–690]	60,000–85,000 [415–585]	85,000–110,000 [585–760]	85,000–110,000 [585–760]	85,000–110,000 [585–760]	85,000–110,000 [585–760]
Yield strength, min, psi [MPa]	40,000 [275]	40,000 [275]	45,000 [310]	30,000 [205]	40,000 [275]	36,000 [250]	50,000 [345]	55,000 [380]	55,000 [380]	45,000 [310]	30,000 [205]	45,000 [310]	30,000 [205]	60,000 [415]	60,000 [415]	60,000 [415]	60,000 [415]
Elongation in 2 in. or 50 mm, min, %	20	20	18	20	20	20	19	20	18	19	20	19	20	20	18	18	18
Reduction of area, min, %	40	40	40	45	40	40	35	40	35	40	45	40	45	40	45	45	45

	Austenitic Steels																					
	Grade																					
	F304	F304H	F304L	F304N	F304LN	F309H	F310H	F316	F316H	F316L	F316N	F316LN	F321H	F347	F347H	F348	F348H	F321	F310	FXM-11	FXM-19	F46
Tensile strength min, ksi [MPa]	70 [485]	70 [485]	65 [450]	80 [550]	70 [485]	70	70	70 [485]	70 [485]	65 [450]	80 [550]	70 [485]	70 [485]	70 [485]	70 [485]	70 [485]	65 [450]	70 [485]	75 [515]	90 [620]	100 [690]	78–100 [540–690]
Yield strength (0.2% offset), min, ksi [MPa]	30 [205]	30 [205]	25 [170]	35 [240]	30 [205]	30	30	30 [205]	30 [205]	25 [170]	35 [240]	30 [205]	30 [205]	30 [205]	30 [205]	30 [205]	25 [170]	30 [205]	30 [205]	50 [345]	55 [380]	32 [220]
Elongation in 2 in. or 50 mm, min, %	30	30	30	25	30	30	30	30	30	30	25	30	30	30	30	30	30	30	30	40	30	40
Reduction of area, min, %	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	35	50	50	50

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Rough Turning and Boring

S1.1 The position of the rough turning and boring in the sequence of manufacturing operations shall be specified.

S2. Transverse Tension Test

S2.1 Instead of test specimens taken in accordance with 8.1.1, the longitudinal axis of the test specimens shall be transverse to the direction of major working of the forging. The results shall conform with requirements of Table 2, with the exception of the ductility limits which shall be as prescribed in Table S1.1.

S3. Alternative Test Specimen Requirements

S3.1 The test requirements for materials of the ASME Boiler and Pressure Code, Section III, Article NB-2223.3, shall be used in place of that specified in 8.1.1.1.

S4. Hydrostatic Test

S4.1 A hydrostatic pressure test shall be applied. The details of the test, including its position in the sequence of manufacturing operations, shall be specified.

S5. Stabilization Heat Treatment

S5.1 When specified, Grades F347 and F321 shall receive stabilization treatment, which shall consist of holding the forging at 1500 to 1600°F [815 to 870°C], for not less than 2 h/in. of thickness and then cooling in the furnace or in still air.

S6. Liquid Penetrant Examination

S6.1 After ferritic forgings have been heat treated by quenching and tempering, all accessible surfaces shall be inspected for quench cracks by the liquid penetrant method in accordance with Test Method E 165 as an alternative to magnetic particle examination.

S7. Marking

S7.1 Forgings shall be marked at a location indicated by the purchaser in the purchase order or drawing.

S8. Forging Requirements

S8.1 Large drum forgings shall be made from solid cast ingots, punched, bored, or trepanned, or from hollow ingots cast in metal molds. The walls of the hollowed or hollow ingots shall be reduced in thickness at least one-half by forging on mandrels.

S8.2 Drum forgings with one solid closed end may be hollow forged in closed dies or on a draw bench provided the metal is worked thoroughly.

S8.3 Drum forgings, either with open ends or one solid closed end, may also be produced by hot extrusion provided the metal is worked thoroughly.

S8.4 Small drum forgings may be made as solid forgings, subsequently bored, provided the purchaser agrees to this method of forging. The cross-sectional area of the solid forgings shall have a reduction by forging from that of the ingot in the ratio of not less than 3:1.

S8.5 Small sections or component parts of pressure vessels, which are to be subsequently assembled to form drums, may be made by expanding on a mandrel under a press or hammer, by hot extrusion or by ring rolling methods, provided the wall thickness is reduced at least one-half in the process.

S8.6 Heads or covers shall be forged as disks, upset from blocks cut from ingots or billets. The length of block before upsetting shall be at least twice the thickness of the as-forged head or cover.

S9. Individual Forging

S9.1 Forgings, whether identical or not identical, shall be produced individually. They shall not be forged in multiple and separated prior to or after heat treatment.

S9.2 The shape and size of individual forgings shall be agreed between the manufacturer and the purchaser by means of a forging drawing or the purchase order.

TABLE S1.1
DUCTILITY LIMITS

	Grade															
	F1	F11, Class 2	F11, Class 3	F11, Class 2	F12	F5	F5A	F9	F6	F21, Class 3	F21, Class 1	F22, Class 3	F22, Class 1	F3V	F46	F22V
Elongation in 2 in. or 50 mm, min, %	20	18	18	19	18	19	19	18	18	18	19	18	20	17	40	17
Reduction of area, min, %	30	35	30	40	25	35	35	35	35	35	35	25	35	35	50	35

	F304	F304H	F304L	F304LN	F304N	F309H	F310	F310H	F316	F316H	F316L	F316LN	F316N	F321	F321H	F347	F347H	F348	F348H	FXM-19	F91
Elongation in 2 in. or 50 mm, min, %	30	30	30	30	25	30	30	30	30	30	30	30	25	30	30	30	30	30	30	30	19
Reduction of area, min, %	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	37	35	35	35	35	40

SPECIFICATION FOR FORGINGS, CARBON AND LOW-ALLOY STEEL, REQUIRING NOTCH TOUGHNESS TESTING FOR PIPING COMPONENTS

SA-350/SA-350M

(Identical with ASTM Specification A 350/A 350M-95b) 98

1. Scope

1.1 This specification covers several grades of carbon and low-alloy steel forged or ring-rolled flanges, forged fittings and valves intended primarily for low-temperature service and requiring notch toughness testing. They are made to specified dimensions, or to dimensional standards, such as the ANSI and API Specifications referenced in Section 2. Although this specification covers some piping components machined from rolled bar and seamless tubular materials (see 4.3.3), it does not cover raw material produced in these product forms.

1.2 No limitation on size is intended beyond the ability of the manufacturer to obtain the specified requirements. However, Class 3 of Grade LF787 is only available in the quenched-and-precipitation, heat-treated condition.

1.3 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified by the purchaser in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1—Refer to Test Methods and Definitions A 370 for notes on significance of notched-bar impact testing.

2. Referenced Documents 98

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 788 Specification for Steel Forgings, General Requirements

E 165 Practice for Liquid Penetrant Inspection Method

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

2.2 *MSS Standard:*

MSS-SP25 Standard Marking System for Valves, Fittings, Flanges and Unions

2.3 *ASME Standard:*

Section IX, Welding Qualifications, ASME Boiler and Pressure Vessel Code

2.4 *AWS Standards:*

A 5.1 Mild Steel Covered Arc-Welding Electrodes

A 5.5 Low-Alloy Steel Covered Arc-Welding Electrodes

2.5 *ANSI Standards:*
B16.5 Steel Pipe Flanges and Flanged Fittings
B16.9 Factory-Made Wrought Steel Butt-Welding Fittings
B16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves
B16.11 Forged Steel Fittings, Socket-Welding and Threaded
B16.30 Unfired Pressure Vessel Flange Dimensions

2.6 *API Standards:*
600 Steel Gate Valves with Flanged or Butt-Welding Ends
602 Compact Design Carbon Steel Gate Valves for Refinery Use
605 Large Diameter Carbon Steel Flanges

98 **3. Ordering Information**

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

3.1.1 Quantity,

3.1.2 Size and pressure class or dimensions (Tolerances and surface finishes should be included),

3.1.3 Specification number, grade, and class if applicable (The year date should be included),

3.1.4 Supplementary requirements, and

3.1.5 Additional requirements (See Table 1 footnotes, 6.1.3.3, 8.1, 13.1, 13.2, and 14.2).

4. Manufacture

4.1 *Melting Process* — The steel shall be produced by any of the following primary processes; open-hearth, basic-oxygen, electric-furnace, or vacuum-induction melting (VIM). The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting using electroslag remelting (ESR), or vacuum-arc remelting (VAR).

4.1.1 The steel shall be fully killed, fine-grain practice.

4.1.2 The molten steel may be vacuum treated prior to or during pouring of the ingot.

4.2 *Discard* — A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

4.3 *Forging Process:*

4.3.1 Material for forgings shall consist of ingots, or forged, rolled, or strandcast blooms, billets, slabs, or bars.

4.3.2 The finished product shall be a forging as defined in the Terminology section of Specification A 788.

4.3.3 Except for flanges of all types, hollow, cylindrically-shaped parts may be machined from rolled bar or seamless tubular materials provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Other parts, excluding flanges of all types, may be machined from hot-rolled or forged bar up through and including NPS 4. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.4 *Heat Treatment:*

4.4.1 After hot working and before reheating for heat treatment, the forging shall be allowed to cool substantially below the transformation range.

4.4.2 Forgings of grades other than Grade LF787 shall be furnished in the normalized, or in the normalized and tempered, or in the quenched and tempered condition described by the following procedures:

4.4.2.1 *Normalize* — Heat to a temperature that produces an austenitic structure, holding sufficient time to attain uniform temperature throughout. Cool uniformly in still air.

4.4.2.2 *Normalize and Temper* — Subsequent to normalize, reheat to 1100°F [590°C] minimum, holding at temperature a minimum of 30 min/in. [30 min/25 mm] of maximum thickness, but in no case less than 30 min. Cool in still air.

4.4.2.3 *Quench and Temper* — The procedure for quenching shall consist of either (1) fully austenitizing the forgings followed by quenching in a suitable liquid medium or (2) using a multiple stage procedure whereby the forging is first fully austenitized and rapidly cooled, then reheated to partially reaustenitize, followed by quenching in a suitable liquid medium. All quenched forgings shall be tempered by reheating to a temperature between 1100°F [590°C] and the lower transformation temperature, holding at temperature a minimum of 30 min/in. [30 min/25 mm] of maximum thickness but in no case less than 30 min. Cool in still air.

4.4.3 Grade LF787 forgings shall be furnished in either the normalized-and-precipitation, heat-treated condition or in the quenched-and-precipitation, heat-treated condition. The heat treatment procedures shall be as follows:

4.4.3.1 *Normalized-and-Precipitation Heat Treated* — Heat to a temperature in the range from 1600 to 1725°F [870 to 940°C], hold at the temperature for a time sufficient to attain uniform temperature throughout, soak at the temperature for not less than ½ hr, and remove from the furnace and cool in air. Subsequently, heat to a temperature in the range from 1000 to 1200°F [540 to 650°C], soak at the temperature for not less than ½ hr, and cool at any convenient rate.

4.4.3.2 *Quenched-and-Precipitation Heat Treated* — Heat to a temperature in the range from 1600 to 1725°F [879 to 940°C], hold at the temperature for a time sufficient to attain uniform temperature throughout, soak at the temperature for not less than ½ hr and quench in a suitable liquid medium by immersion; reheat to a temperature in the range from 1000 to 1225°F [540 to 665°C], hold at the temperature for not less than ½ hr, and cool at any convenient rate.

5. Chemical Composition

5.1 *Heat Analysis:*

5.1.1 An analysis of each heat of steel shall be made by the steel producer from samples taken preferably during the pouring of the heat. The results shall conform to Table 1.

5.1.2 Steels to which lead has been added shall not be used.

5.1.3 Intentional additions of copper, nickel, chromium, or molybdenum to Grades LF1, LF2, and LF6 are not permitted. Intentional additions of copper, chromium, or molybdenum to Grades LF3 or LF5 are not permitted. Intentional additions of chromium or molybdenum to Grade LF9 are not permitted.

5.2 *Product Analysis* — An analysis may be made by the purchaser from a forging representing each heat of steel. Samples for analysis shall be taken midway between center and surface of solid forgings, midway between inner and outer surfaces of hollow forgings, midway between center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 1, with the tolerances as stated in Table 2.

5.3 *Methods of Analysis* — Test Methods, Practices, and Terminology A 751 shall apply.

6. Mechanical Properties

6.1 *Tension Tests:*

6.1.1 *Requirements* — The material shall conform to requirements for tensile properties in Table 3.

6.1.1.1 The test specimen shall be obtained from a rough or finished production forging, or prolongation thereof, or it may be obtained from separately forged test blanks from the same heat of steel as the production forging. The test blank shall be reduced by forging in a manner similar to that for the products represented, and shall receive approximately the same hot working and reduction and the same heat treatment as the finished products represented. The test material shall be treated in the same furnace at the same time as the forging it represents, subject to the requirements of 6.1.2.1.

6.1.1.2 The test specimen shall represent all forgings from the same heat and heat-treatment load whose maximum thicknesses do not exceed the thickness of the test forging or blank by more than ¼ in. [6 mm].

6.1.2 *Number of Tests* — One tension test at room temperature shall be made in accordance with 6.1.1.2 from each heat in each heat-treatment load.

6.1.2.1 If heat treatment is performed in either a continuous or a batch-type furnace controlled with ±25°F [±14°C] of the required heat-treatment temperature and equipped with recording pyrometers so that complete records of heat treatment are available and if the same heat-treating cycles are used on the forgings represented by the tension test, then one tension test from each heat shall be required, instead of one tension test from each heat in each heat treatment load in accordance with 6.1.1.2.

6.1.3 *Test Locations and Orientations* — The test specimen shall be removed from the heaviest section of the forging or test blank, at locations described in 6.1.3.1, 6.1.3.2, 6.1.3.3, or as close to these locations as practical, subject to forging size and geometry.

6.1.3.1 For forgings or test blanks having a maximum heat-treated thickness, *T*, of 2 in. [50 mm] or less, the longitudinal axis of the test specimen shall be taken at mid-thickness and its mid-length shall be at least 2 in. [50 mm] from a second heat-treated

surface, exclusive of the *T* dimension surfaces. (This is normally referred to as ½ *T* by 2 in. [50 mm]).

6.1.3.2 For forgings or test blanks having a maximum heat-treated thickness, *T*, greater than 2 in. [50 mm], the central axis of the test specimen shall be taken at least ¼ *T* from the nearest heat-treated surface and at least *T* or 4 in. [100 mm], whichever is less, from any second heat-treated surface.

6.1.3.3 With prior purchaser approval, tests may be taken at a depth (*t*) corresponding to the distance from the area of significant loading to the nearest heat-treated surface and at least twice this distance (2*t*) from any second surface. However, the test depth shall not be nearer to one treated surface than ¾ in. [19 mm] and to the second treated surface than 1½ in. [38 mm]. This method of test location would normally apply to contour-forged parts, or parts with thick cross-sectional areas where ¼ *T* × *T* testing (6.1.3.2) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

6.1.3.4 The test specimen shall have its longitudinal axis located parallel to the direction of major working of the forging or test blank.

6.1.4 *Test Method* — Testing shall be performed in accordance with Test Methods and Definitions A 370. The test specimen shall be as large as is practicable and shall be machined to the form and dimensions of Fig. 6 of Test Methods and Definitions A 370. When seamless tubular materials are used, testing shall be performed on longitudinal specimens in accordance with Annex A2, Steel Tubular Products, of Test Methods and Definitions A 370.

6.2 *Impact Test:*

6.2.1 *Requirements* — The material shall conform to the requirements for impact properties in Table 4 when tested at the applicable standard temperature in Table 5 within the limits of 6.2.4.2 and 6.2.4.3. When subsize specimens are used, the impact energy values obtained shall conform to Table 6 at energy values proportional to standard size. Exceptions to this requirement are permissible when Supplement S4 is specified by the purchaser. Impact tests may be made at temperatures different from those in Table 5, provided that the test temperature is at least as low as the intended service temperature, and that the forging is suitably marked to identify the reported test temperature.

6.2.1.1 The test specimens shall be machined from material obtained as in 6.1.

6.2.2 *Number of Tests* — Three specimens shall constitute one test set. There shall be the same number of test sets as tension tests in 6.1.2.

6.2.3 *Test Locations and Orientations* — The test specimen shall be located and oriented as described in 6.1.3. The area under the notch of the impact test specimen shall be used to locate the specimen with respect to the second heat-treated surface. The base of the notch shall be perpendicular to the nearest heat-treated surface.

6.2.4 *Test Method* — The notched bar impact test shall be made in accordance with the procedure for the Charpy V-notch type test as described in Test Methods and Definitions A 370.

6.2.4.1 Standard size specimens shown in Fig. 10 of Test Methods and Definitions A 370 shall be used for the impact test. Where the material is of insufficient thickness, or the shape of the forging precludes standard size, the largest obtainable subsize specimen described in Test Methods and Definitions A 370 shall be used.

6.2.4.2 Where subsize specimens are used and represent forged material with thicknesses equal to or greater than 0.394 in. [10 mm], and where the largest obtainable specimen has a width along the notch of at least 8 mm, such specimen shall be tested at the temperature in Table 5. Where the largest obtainable specimen has a width along the notch less than 8 mm, the temperature for testing shall be lower than the temperature in Table 5 by the amount shown in Table 7 for the actual specimen width tested.

6.2.4.3 Where subsize specimens are used and represent forged material with thicknesses less than 0.394 in. [10 mm], and where the largest obtainable specimen has a width along the notch of at least 80% of the forging thickness, the specimen shall be tested at the temperature in Table 5. Where the largest obtainable specimen has a width along the notch of less than 80% of the material thickness, the temperature for testing shall be lower than the temperature in Table 5 by an amount equal to the difference (referring to Table 7) between the temperature reduction corresponding to the thickness of the material represented, and the temperature reduction corresponding to the specimen width actually tested.

6.3 *Hardness Test:*

6.3.1 Except when only one forging is produced, a minimum of two forgings shall be hardness tested per batch or continuous run as defined in 6.1.2.1 to

ensure that hardness of the forgings does not exceed 197 HB after heat treatment for mechanical properties. The hardness measurements shall be made in accordance with Test Methods and Definitions A 370. When only one forging is produced, it shall be hardness tested to ensure that it meets the 197 HB maximum of this specification. The purchaser may verify that this requirement has been met by testing at any location on the forging, provided that such testing does not render the forging useless.

7. Hydrostatic Test

7.1 Forgings manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished forging. Such tests shall be conducted by the forging manufacturer only when Supplementary Requirement S9 is specified.

8. Workmanship, Finish, and Appearance

8.1 The forgings shall conform to the dimensions, tolerances, and finish as specified on the purchaser's drawing or order. Unless otherwise specified in the purchase order, the fittings shall be cleaned to remove all scale and processing compounds prior to final surface examination. The cleaning process shall not injure the surface finish, material properties, or the metallurgical structure. The cleaned fittings shall be protected to prevent recontamination. Protective coatings on socket weld and butt welding fittings shall be suitable for subsequent welding without removal of the coating. When specified in the purchase order, parts may be furnished in the as-formed or as-forged condition.

8.2 The forgings shall be free of injurious imperfections as defined below and shall have a workmanlike finish. At the discretion of the inspector representing the purchaser, finished forgings shall be subject to rejection if surface imperfections acceptable under 8.3 are not scattered but appear over a large area in excess of what is considered a workmanlike finish.

8.3 *Depth of Injurious Imperfections* — Selected typical linear surface imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness of the finished forging, such imperfections shall be considered injurious.

8.4 *Machining or Grinding Imperfections Not Classified as Injurious* — Surface imperfections not classified as injurious shall be treated as follows:

8.4.1 Forgings showing seams, laps, tears, or slivers not deeper than 5% of the nominal wall thickness or $^{1}/_{16}$ in. [1.6 mm], whichever is less, need not have these imperfections removed. If the imperfections require removal, they shall be removed by machining or grinding.

8.4.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed the limitations set forth in 8.3 and is not deeper than $^{1}/_{16}$ in. [1.6 mm]. If such imperfections are deeper than $^{1}/_{16}$ in. [1.6 mm], but do not encroach on the minimum wall thickness of the forging, they shall be removed by grinding to sound metal.

8.4.3 When imperfections have been removed by grinding or machining, the outside dimension at the point of grinding or machining will be reduced by the amount removed. Should it be impracticable to secure a direct measurement of wall thickness at the point of grinding, or at imperfections not required to be removed, the thickness shall be determined by deducting the amount removed by grinding, from the nominal finished wall thickness of the forging. The remainder shall not be less than the minimum specified or required wall thickness.

9. Retests

9.1 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

10. Rework and Retreatment

10.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings represented, and shall retest to the applicable requirements.

10.2 Individually tested forgings meeting all requirements shall be acceptable.

10.3 *Repair by Welding* — Weld repairs shall be permitted (see Supplementary Requirements S10) at the discretion of the manufacturer with the following limitations and requirements:

10.3.1 Repair by welding shall be made using welding procedures and welders qualified in accordance with ASME Section IX of the Code. The weld procedure qualification test shall also include impact tests of the weld metal and heat-affected zone. All impact test

specimens shall have the longitudinal axis transverse to the weld and the base of the notch normal to the weld surface. Weld specimens shall have the notch in weld metal and heat-affected zone specimens shall have the notch in the heat-affected zone. The specimens shall be as large as permitted by the weldment thickness. Where full-size specimens can be obtained and where there is sufficient weldment thickness, the weld specimen shall be taken with one side of the specimen within $\frac{1}{16}$ in. [1.6 mm] of the weld surface. Heat-affected zone impact test specimens shall be taken at the same depth and locations applicable to the forging in 6.1.3.1 and 6.1.3.2. When forgings are thermally treated after repair welding, the weld procedure test plate shall be subjected to the same thermal treatment. The mechanical properties of the weld procedure qualification test shall conform to Section 6.

10.3.2 Defects shall be completely removed by chipping or grinding to sound metal as verified by magnetic particle, or liquid penetrant inspection prior to welding.

10.3.3 For Grade LF1 forgings, and LF2 forgings that are to be only stress-relieved after repair welding, the weld metal shall be deposited using carbon steel electrodes E7015, E7016, or E7018, complying with AWS A5.1. For Grade LF2 forgings in all other conditions of post-weld heat treatment, the weld metal shall be deposited using low-alloy steel electrodes E7015-A1, E7016-A1, or E7018-A1, complying with AWS 5.5; for Grade LF3 forgings the weld metal shall be deposited using low-alloy steel electrodes E8016-C2 or E8018-C2, complying with AWS A5.5; for Grades LF5, LF9, and LF787 forgings, the weld metal shall be deposited using low-alloy steel electrodes E8016-C1 or E8018-C1, complying with AWS A5.5. For Grade LF6, the electrodes shall be low-hydrogen, E-XX15, E-XX16, or E-XX18, complying with AWS A5.1 or A5.5, as applicable.

10.3.4 After repair welding, the area welded shall be completely free of defects as verified by magnetic particle or liquid penetrant inspection.

10.3.5 Forgings repair welded in the normalized, normalized and tempered, or the quenched and tempered conditions shall be stress-relieved after repair welding at 1100°F [590°C] minimum, but not higher than the temperature previously used for tempering the base metal of the same forging, or shall be re-heat treated in accordance with 4.4.

10.3.6 When the purchaser specifies Supplementary Requirement S5, the same requirements shall apply to the weld procedure qualification tests.

10.3.7 Repair by welding shall not exceed 10% of the surface area of the forging or $33\frac{1}{3}$% of the wall thickness of the finished forging, or $\frac{3}{8}$ in. [9.5 mm], whichever is less, without prior approval of the purchaser.

10.3.8 When approval of the purchaser is obtained, the limitations set forth in 10.3.7 may be exceeded, but all other requirements of 10.3 shall apply.

11. Inspection

11.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with the purchase order. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed, except for product analysis (see 5.2).

12. Rejection and Rehearing

12.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

12.2 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed to between the manufacturer and the purchaser.

13. Certification

13.1 For forgings made to specified dimensions when agreed to by the purchaser, and for forgings made to dimensional standards, application of identification marks as required in Section 14 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification.

13.2 When test reports are required, they shall include certification that all requirements of this specification have been met, and shall be traceable to the forging represented. The specification designation included on test reports shall include year of issue and revision letter, if any. The manufacturer shall provide the following where applicable:

13.2.1 Type heat treatment, Section 4,

13.2.2 Chemical analysis results, Section 5 (Table 1),

13.2.3 Product analysis results, 5.2 (Tables 1 and 2),

13.2.4 Tensile property results, Section 6 (Table 3) report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent,

13.2.5 Impact test results, 6.2 (Tables 4, 5, 6, and 7),

13.2.6 Hardness results, 6.3.1,

13.2.7 Any supplementary testing required by the purchase order, and

13.2.8 If repaired by welding, 14.1.2, letter W is to follow the ASTM designation.

14. Product Marking

14.1 Identification marks consisting of the ASTM specification number grade and class, manufacturer's name (Note 2) or symbol, the heat number or manufacturer's heat identification, size, and service rating, if applicable, shall be permanently placed on each forging in a position that will not affect the usefulness of the forging. The specification number marked on the forgings need not include specification year of issue and revision letter. The Standard Marking System of Valves, Fittings, Flanges, and Unions (SP25) of the Manufacturer's Standardization Society of the Valve and Fittings Industry may be followed except the word "steel" shall not be substituted for the ASTM designation.

NOTE 2—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

14.1.1 If the forgings have been quenched and tempered or quenched-and-precipitation heat treated, the letters QT shall be stamped on the forgings following the ASTM designation.

14.1.2 Forgings repaired by welding shall be marked with the letter W following the ASTM designation.

14.2 If identification stamps are objectionable and detrimental to the forging, and when so stated on the purchase order, the marks may be painted or stenciled on the forging, or stamped on a metal or plastic tag which shall be securely attached to the forging.

14.3 When test reports are required, additional marks shall be used as necessary to identify the part with the test report.

14.4 If the test temperature is other than the standard temperature specified in Table 5, the mark shall also include the suffix letter S to the grade and class and the test temperature. A prefix 0 to the test temperature shall indicate a less than 0°F [−17.8°C] value. For example, LF2S 0175 denotes a test temperature of −175°F [−115°C] for an LF2 part.

14.5 *Bar Coding* — In addition to the requirements in 14.1, 14.2, 14.3, and 14.4, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag. **98**

15. Keywords

15.1 carbon equivalent; pipe fittings, steel; piping applications; pressure containing parts; steel flanges; steel forgings, alloy; steel forgings, carbon; steel valves; temperature service applications, low **98**

98

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, wt. %						
	Grade LF1	Grade LF2	Grade LF3	Grade LF5	Grade LF6	Grade LF9	Grade LF787
Carbon, max	0.30	0.30	0.20	0.30	0.22	0.20	0.07
Manganese	0.60–1.35	0.60–1.35	0.90 max	0.60–1.35	1.15–1.50	0.40–1.06	0.40–0.70
Phosphorus, max	0.035	0.035	0.035	0.035	0.025	0.035	0.025
Sulfur, max	0.040	0.040	0.040	0.040	0.025	0.040	0.025
Silicon[A]	0.15–0.30	0.15–0.30	0.20–0.35	0.20–0.35	0.15–0.30	. . .	0.40 max
Nickel	0.40 max[B]	0.40 max[B]	3.3–3.7	1.0–2.0	0.40 max[B]	1.60–2.24	0.70–1.00
Chromium	0.30 max[B,C]	0.30 max[B,C]	0.30 max[C]	0.30 max[C]	0.30 max[B,C]	0.30 max[C]	0.60–0.90
Molybdenum	0.12 max[B,C]	0.12 max[B,C]	0.12 max[C]	0.12 max[C]	0.12 max[B,C]	0.12 max[C]	0.15–0.25
Copper	0.40 max[B]	0.40 max[B]	0.40 max[C]	0.40 max[C]	0.40 max[B]	0.75–1.25	1.00–1.30
Columbium	0.02 max[D]	0.02 max[D]	0.02 max[D]	0.02 max[D]	0.02 max[D]	0.02 max[D]	0.02 min
Vanadium	0.03 max[D]	0.03 max[D]	0.03 max[D]	0.03 max[D]	0.04–0.11	0.03 max[D]	0.03 max[D]
Nitrogen	. . .	. . .	. . .	. . .	0.01–0.030	. . .	. . .

[A] When vacuum carbon-deoxidation is required by Supplementary Requirement S11, the silicon content shall be 0.12% maximum.
[B] The sum of copper, nickel, chromium, and molybdenum shall not exceed 1.00% on heat analysis.
[C] The sum of chromium and molybdenum shall not exceed 0.32% on heat analysis.
[D] By agreement, the heat analysis limit for vanadium or columbium, or both, may be increased up to 0.10% and 0.05%, respectively.

TABLE 2
PRODUCT ANALYSIS TOLERANCE

Element	Limit or Maximum of Specified Range	Permissible Variations Over Maximum Limit or Under Minimum Limit for Size Ranges Shown, %			
		To 100 in.^{2} [645 cm^2] incl[A]	Over 100 to 200 in.^{2} [645 to 1290 cm^2] incl[A]	Over 200 to 400 in.^{2} [1290 to 2580 cm^2] incl[A]	Over 400 to 800 in.^{2} [2580 to 5160 cm^2] incl[A]
Carbon	to 0.30 incl	0.01	0.02	0.03	0.04
Manganese	to 0.90 incl	0.03	0.04	0.05	0.06
	over 0.90 to 1.35 incl	0.04	0.05	0.06	0.07
	over 1.35 to 1.50 incl	0.10	0.10	0.10	0.10
Phosphorus	over maximum only	0.005	0.010	0.010	0.010
Sulfur	over maximum only	0.005	0.010	0.010	0.010
Silicon	to 0.35 incl	0.02	0.02	0.03	0.04
Nickel	up to and incl 1.00	0.03	0.03	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05	0.05	0.05
	over 2.00 to 5.20 incl	0.07	0.07	0.07	0.07
Copper	up to and incl 0.75	0.03	0.03	0.03	0.03
	over 0.75 to 1.30 incl	0.05	0.05	0.05	0.05
Chromium	to 0.90 incl	0.04	0.04	0.04	0.04
Molybdenum	to 0.20 incl	0.01	0.01	0.01	0.01
	over 0.20 to 0.40 incl	0.03	0.03	0.03	0.03
Columbium	to 0.10 incl	0.01	0.01	0.01	0.01
Vanadium	up to and incl 0.10	0.01	0.01	0.01	0.01
	0.11 to 0.25 incl	0.02	0.02	0.02	0.02
Nitrogen	up to and incl 0.02	0.005	0.005	0.005	0.005
	over 0.02 to 0.19 incl	0.01	0.01	0.01	0.01

[A] The significant cross section of the forging shall be governed by the main body diameter.

TABLE 3
TENSILE PROPERTIES AT ROOM TEMPERATURE[A]

	Grades							
	LF1 and LF5 Class 1	LF2	LF3 and LF5 Class 2	LF6		LF9	LF787	
				Class 1	Class 2		Class 2	Class 3
Tensile strength, ksi [MPa]	60–85 [415–585]	70–95 [485–655]	70–95 [485–655]	66–91 [455–630]	75–100 [515–690]	63–88 [435–605]	65–85 [450–585]	75–95 [515–655]
Yield strength, min, ksi [MPa][B,C]	30 [205]	36 [250]	37.5 [260]	52 [360]	60 [415]	46 [315]	55 [380]	65 [450]
Elongation:								
Standard round specimen, or small proportional specimen, min % in 4D gage length	25	22	22	22	20	25	20	20
Strip specimen to wall thickness $^{5}/_{16}$ in. (7.94 mm) and over and for all small sizes tested in full section; min % in 2 in. (50 mm)	28	30	30	30	28	28	28	28
Equation for calculating min elongation for strip specimens thinner than $^{5}/_{16}$ in. (7.94 mm); min % in 2 in. (50 mm) t = actual thickness in inches	48t + 13	48t + 15	48t + 15	48t + 15	48t + 13	48t + 13	48t + 13	48t + 13
Reduction of area, min, %	38	30	35	40	40	38	45	45

[A] See 6.3 for hardness tests.
[B] Determined by either the 0.2% offset method or the 0.5% extension under load method.
[C] For round specimens only.

TABLE 4
CHARPY V-NOTCH ENERGY REQUIREMENTS FOR STANDARD SIZE [10 by 10 mm] SPECIMENS

Grade	Minimum Impact Energy Required for Average of Each Set of Three Specimens, ft-lbf[J]	Minimum Impact Energy Permitted for One Specimen only of a Set, ft-lbf[J]
LF1 and LF9	13 [18]	10 [14]
LF2, LF3, LF5 Classes 1 and 2, and LF787 and Classes 2 and 3	15 [20]	12 [16]
LF6 Class 1	15 [20]	12 [16]
LF6 Class 2	20 [27]	15 [20]

TABLE 5
STANDARD IMPACT TEST TEMPERATURE FOR STANDARD SIZE [10 by 10 mm] SPECIMENS

Grade	Test Temperature, °F [°C]
LF1	−20 [−28.9]
LF2	−50 [−45.6]
LF3	−150 [−101.1]
LF5 Classes 1 and 2	−75 [−59.4]
LF6 Classes 1 and 2	−60 [−50]
LF9	−100 [−73.3]
LF787 Class 2	−75°F [−59°C]
LF787 Class 3	−100°F [−73°C]

TABLE 6
MINIMUM EQUIVALENT ABSORBED ENERGY FT-LBF (J) FOR VARIOUS SPECIMEN SIZES[A]

Standard Size [10 by 10 mm]	3/4 Size [10 by 7.5 mm]	2/3 Size [10 by 6.6 mm]	1/2 Size [10 by 5 mm]	1/3 Size [10 by 3.3 mm]	1/4 Size [10 by 2.5 mm]
15 [20]	12 [16]	10 [14]	8 [11]	5 [7]	4 [6]
13 [18]	10 [14]	9 [12]	7 [10]	5 [7]	4 [6]
12 [16]	10 [14]	9 [12]	7 [10]	4 [6]	3 [5]
10 [14]	8 [11]	7 [10]	5 [7]	3 [5]	3 [5]

[A] Straight-line interposition for intermediate values is permitted.

TABLE 7
CHARPY IMPACT TEST TEMPERATURE REDUCTION BELOW TABLE 5 TEST TEMPERATURE WHEN THE SUBSIZE CHARPY IMPACT WIDTH ALONG NOTCH IS LESS THAN 80% OF THE FORGING THICKNESS

Size of Bar	Thickness of the Material Represented (see 6.2.4.3), or Charpy, Impact Specimen Width Along the Notch[A], in. [mm]	Temperature Reduction, °F [°C]
Standard	0.394 [10]	0 [0]
Standard	0.354 [9]	0 [0]
Standard	0.315 [8]	0 [0]
3/4-size	0.295 [7.5]	5 [3]
3/4-size	0.276 [7]	8 [5]
2/3-size	0.262 [6.67]	10 [6]
2/3-size	0.236 [6]	15 [8]
1/2-size	0.197 [5]	20 [11]
1/2-size	0.158 [4]	30 [17]
1/3-size	0.131 [3.33]	35 [20]
1/3-size	0.118 [3]	40 [22]
1/4-size	0.099 [2.5]	50 [28]

[A] Straight-line interpolation for intermediate values is permitted.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order:

S1. Macroetch Test

S1.1 A sample forging shall be sectioned and etched to show flow lines and internal soundness. The tests shall be conducted according to Method E 381.

S1.2 Acceptance limits shall be as agreed upon between the manufacturer and the purchaser.

S2. Product Analysis

S2.1. A product analysis shall be made from one randomly selected forging representing each size and shape of forging on the order and the results shall not vary from the ranges or limits specified in Table 1 by more than the amounts specified in Table 2.

S2.2 If the analysis fails to comply, each forging shall be checked or the lot rejected. All results shall be reported to the purchaser.

S3. Additional Mechanical Tests

S3.1 In addition to the requirements of Section 6, the heat identification shall be marked on each forging, and one tension specimen and one test set of three impact specimens shall be obtained from a representative forging or test blank, the procedure for taking the test material to be agreed upon between the manufacturer and purchaser.

S3.2 The results of the test shall comply with 6.1.1 and 6.2.1, and shall be reported to the purchaser.

S4. Other Impact Test Temperatures

S4.1 Impact test temperatures lower or higher than the standard temperature in Table 5 of this specification shall be used.

S4.1.1 When higher test temperatures are employed, the actual test temperature may not be higher than that given in Table S1.1.

S4.2 The test temperature shall be specified by the purchaser. When subsize specimens are used, the manufacturer shall adjust test temperature in accordance with the size restrictions of 6.2.4.2 and 6.2.4.3.

S4.3 The forging shall be marked with the specified test temperature in accordance with 14.4. A lower temperature shall not be marked on the forging because of the use of subsize specimens.

S4.4 The test results shall comply with Table 4 for standard size specimens, and with Table 6 for subsize specimens.

S5. Stress-Relieved Test Specimens

S5.1 The test specimens shall be stress relieved. Stress relieving shall be done after heat treatment in 4.4 and before machining the specimens from the heat-treated test material.

S5.2 The purchaser shall furnish the forging manufacturer with details of the stress-relief treatment desired.

S6. Lateral Expansion

S6.1 Lateral expansion of the Charpy V-notch test in accordance with Section 23 of Test Methods and Definitions A 370 shall be measured and reported.

S7. Magnetic Particle Examination

S7.1 All surfaces of the finished forging shall be examined by a magnetic particle method. This method shall be in accordance with Test Method A 275/A 275M.

S7.2 Acceptance limits shall be as agreed upon between the manufacturer and purchaser.

S8. Liquid Penetrant Examination

S8.1 All surfaces shall be examined by a liquid-penetrant method in accordance with Practice E 165.

S8.2 Acceptance limits shall be as agreed upon between the manufacturer and purchaser.

S9. Hydrostatic Testing

S9.1 A hydrostatic test at a pressure agreed upon between the manufacturer and purchaser shall be applied by the manufacturer.

S10. Repair Welding

S10.1 No repair welding shall be permitted without prior approval of the purchaser.

S11. Vacuum Carbon-Deoxidized Steels

S11.1 Material made to Grades LF1, LF2, LF3, LF5, and LF9 shall be vacuum carbon-deoxidized, in which case the silicon content shall be 0.12% maximum. The test report shall indicate that the steel was vacuum carbon-deoxidized.

S12. Special Impact Test Requirements for Flanges (Note 3)

S12.1 Charpy test specimens shall be cut from an actual flange representing each size, heat, and heat-treatment lot. If more than one size flange is represented by the same heat and heat-treatment lot, the maximum size flange shall be considered representative.

S12.2 The number, location, and orientation of the test specimens shall be stated on the order.

S12.3 The test results shall comply with Table 4 for standard size specimens, and with Table 6 for subsize specimens.

NOTE 3—These special requirements should be considered for services when the applied stresses approach the maximum permissible limits of the governing code, or the installation is subject to severe cyclic conditions (7000 or more cycles over the expected life of the installation), or both.

S13. Carbon Equivalent

S13.1 The maximum carbon equivalent based on heat analysis shall be as shown in Table S13.1.

S13.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S13.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

TABLE S1.1
MAXIMUM SUPPLEMENTAL TEST TEMPERATURES

Grade	Maximum Test Temperature, °F (°C)
LF1	−10 [−23]
LF2	−35 [−37]
LF3	−125 [−87]
LF3, Classes 1 and 2	−60 [−51]
LF6, Classes 1 and 2	−40 [−40]
LF9	−80 [−62]
LF787, Class 2	−60 [−51]
LF787, Class 3	−80 [−62]

TABLE S13.1
MAXIMUM CARBON EQUIVALENT VALUE

Grade	Max. Thickness Less Than or Equal to 2 in.	Max. Thickness Greater Than 2 in.
LF1	0.45	0.46
LF2	0.47	0.48
LF6 CL1	0.45	0.46
LF6 CL2	0.47	0.48

SPECIFICATION FOR CASTINGS, AUSTENITIC, AUSTENITIC-FERRITIC (DUPLEX), FOR PRESSURE-CONTAINING PARTS

SA-351/SA-351M

(Identical with ASTM Specification A 351/A 351M-94a except for editorial differences in 10.1.)

1. Scope

1.1 This specification covers austenitic and austenitic-ferritic (duplex) steel castings for valves, flanges, fittings, and other pressure-containing parts (Note 1).

NOTE 1 — Carbon steel castings for pressure-containing parts are covered by Specification A 216/A 216M, and low-alloy steel castings by Specification A 217/A 217M.

1.2 A number of grades of austenitic and austenitic-ferritic steel castings are included in this specification. Since these grades possess varying degrees of suitability for service at high temperatures or in corrosive environments, it is the responsibility of the purchaser to determine which grade shall be furnished. Selection will depend on design and service conditions, mechanical properties, and high-temperature or corrosion-resistant characteristics, or both.

1.2.1 Because of thermal instability, Grades CE20N, CF3A, CF3MA, and CF8A are not recommended for service at temperatures above 800°F [425°C].

1.2.2 Because of embrittlement phases, Grade CD4MCu is not recommended for service at temperatures above 600°F [316°C].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 488/A 488M Practice for Steel Castings, Welding, Qualification of Procedures and Personnel

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

E 165 Test Method for Liquid Penetrant Examination

E 709 Guide for Magnetic Particle Examination

2.2 *Manufacturers Standardization Society of the Valve and Fittings Industry Standard:*

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Components (Visual Method)

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M, including the supplementary requirements that are indicated in the purchase order. Failure to comply

with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

3.2 The post weld heat treatment requirements of Supplementary Requirement S11 may be specified when austenitic castings other than HK, HT, or CT15C are to be subjected to severe corrosive service.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 Supplementary requirements desired, including the standards of acceptance.

5. Process

5.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen decarburization (AOD).

6. Heat Treatment

6.1 All castings shall receive a heat treatment proper to their design and chemical composition, except the HK, HT, and CT15C grades, which shall be furnished in the as-cast condition.

6.2 Grade CD-4MCu shall be heated to 1900°F [1040°C] minimum and Grade CE8MN shall be heated to 2050°F [1120°C] minimum for sufficient time to heat casting uniformly to temperature and then quenched in water or rapidly cooled by other means.

6.3 The austenitic grades, except Grades HK, HT, and CT15C, shall be solution-treated by the manufacturer.

6.4 Grade CK-3MCuN shall be heated to 2100°F [1150°C] minimum for sufficient time to heat casting uniformly to temperature and then quenched in water or rapidly cooled by other means.

NOTE 2 — Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and in some cases to meet mechanical properties. Minimum heat-treat temperatures are specified; however, it is sometimes necessary to heat-treat at higher temperatures, hold for some minimum time at temperature and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

6.5 Grade CN-3MN shall be heated to 2100°F [1150°C] minimum, held for sufficient time to heat the casting to temperature, then quenched in water or cooled rapidly by other means.

6.6 Grade CD3MWCuN shall be solution-treated at 2010°F [1100°C] minimum for sufficient time to heat casting uniformly to temperature and then quenched in water or rapidly cooled by other means.

6.7 Grade CE20N shall be heated to 2225°F [1218°C] minimum, held for sufficient time to heat uniformly to temperature, and quenched in water or the castings may be furnace-cooled to 2050°F [1121°C] minimum, held for 15 min minimum and then quenched by water or rapidly cooled by other means.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Tensile Properties

8.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 2.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP 55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9.2 When additional inspection is desired, Supplementary Requirements S5, S6, and S10 may be ordered.

9.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

10. Repair by Welding

10.1 Repairs shall be made using procedures and welders qualified under Section IX of the ASME Boiler and Pressure Vessel Code.

10.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in. [65 cm], shall be radiographed to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S6 specified, weld repairs shall be inspected by liquid penetrant examination to the same standards that are used to inspect the castings.

NOTE 3 — When austenitic steel castings are to be used in services where they will be subject to stress corrosion, the purchaser should so indicate in his order and such castings should be solution-heat treated following all weld repairs.

TABLE 1
CHEMICAL REQUIREMENTS

Element, % (max, Except Where Range is Given)	CF3, CF3A	CF8, CF8A	CF3M, CF-3MA	CF8M	CF3MN	CF8C	CF10	CF-10M	CH8	CH10	CH20	CK20	HK30	HK40	HT30	CF-10MC	CN7M	CN-3MN	CD-4MCu	CE8MN	CG-6MMN	CG8M	CF10S-MnN	CT15C	CK-3MCuN	CE20N	CG-3M	CD3M-WCuN [Note (3)]
Carbon	0.03	0.08	0.03	0.08	0.03	0.08	0.04–0.10	0.04–0.10	0.08	0.04–0.10	0.04–0.20	0.04–0.20	0.25–0.35	0.35–0.45	0.25–0.35	0.10	0.07	0.03 max	0.04	0.08	0.06	0.08	0.10	0.05–0.15	0.025	0.20	0.03	0.03
Manganese	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	2.00	1.50	1.50	2.00 max	1.00	1.00	4.00–6.00	1.50	7.00–9.00	0.15–1.50	1.20	1.50	1.50	1.00
Silicon	2.00	2.00	1.50	1.50	1.50	2.00	2.00	1.50	1.50	2.00	2.00	1.75	1.75	1.75	2.50	1.50	1.50	1.00 max	1.00	1.50	1.00	1.50	3.50–4.50	0.50–1.50	1.00	1.50	1.50	1.00
Sulfur	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.010 max	0.04	0.040	0.030	0.04	0.030	0.03	0.010	0.040	0.04	0.025
Phosphorus	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040 max	0.04	0.040	0.040	0.04	0.060	0.03	0.045	0.040	0.04	0.030
Chromium	17.0–21.0	18.0–21.0	17.0–21.0	18.0–21.0	17.0–21.0	18.0–21.0	18.0–21.0	18.0–21.0	22.0–26.0	22.0–26.0	22.0–26.0	23.0–27.0	23.0–27.0	23.0–27.0	13.0–17.0	15.0–18.0	19.0–22.0	20.0–22.0	24.5–26.5	22.5–25.5	20.50–23.50	18.0–21.0	16.0–18.0	19.0–21.0	19.5–20.5	23.0–26.0	18.0–21.0	24.0–26.0
Nickel	8.0–12.0	8.0–11.0	9.0–13.0	9.0–12.0	9.0–13.0	9.0–12.0	8.0–11.0	9.0–12.0	12.0–15.0	12.0–15.0	12.0–15.0	19.0–22.0	19.0–22.0	19.0–22.0	33.0–37.0	13.0–16.0	27.5–30.5	23.5–25.5	4.75–6.00	8.0–11.0	11.50–13.50	9.0–13.0	8.0–9.0	31.0–34.0	17.5–19.5	8.0–11.0	9.0–13.0	6.5–8.5
Molybdenum	0.50	0.50	2.0–3.0	2.0–3.0	2.0–3.0	0.50	0.50	2.0–3.0	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.75–2.25	2.0–3.0	6.0–7.0	1.75–2.25	3.0–4.5	1.50–3.00	3.0–4.0	...	...	6.0–7.0	0.50	3.0–4.0	3.0–4.0
Columbium (niobium)	...	...	...	...	...	[Note (1)]	...	...	...	...	...	...	...	...	...	[Note (2)]	...	...	...	...	0.10–0.30	...	...	0.50–1.50	...	...	...	...
Vanadium	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.10–0.30	...	...	...	...	...	...	...
Nitrogen	...	...	...	...	0.10–0.20	...	...	...	...	...	...	...	...	...	...	...	...	0.18–0.26	...	0.10–0.30	0.20–0.40	...	0.08–0.18	...	0.18–0.24	0.08–0.20	...	0.20–0.30
Copper	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3.0–4.0	0.75 max	2.75–3.25	...	...	...	...	...	0.50–1.00	...	...	0.5–1.0
Tungsten	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.5–1.0
Iron	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Bal	...	...

GENERAL NOTE: Tungsten is a new element for Table 1.

NOTES:
(1) Grade CF8C shall have a columbium content of not less than 8 times the carbon content but not over 1.00%.
(2) Grade CF10MC shall have a columbium content of not less than 10 times the carbon content but not over 1.20%.
(3) % Cr + 3.3% Mo + 16% N ≥ 40.

TABLE 2
TENSILE REQUIREMENTS

	CF3	CF3A	CF8	CF8A	CF3M	CF3MA	CF8M	CF3MN	CF8C	CF10	CF10M	CH8	CH10	CH20	CK20	HK30	HK40	HT30	CF10MC	CN7M	CN3MN	CD4MCu	CE8MN	CG 6MMN	CG8M	CF10S-MnN	CT15C	CK3M-CuN	CE20N	CG3M	CD3M-WCuN
Tensile strength, min, ksi [MPa]	70 [485]	77 [530]	70 [485]	77 [530]	70 [485]	80 [550]	70 [485]	75 [515]	70 [485]	70 [485]	70 [485]	65 [450]	70 [485]	70 [485]	65 [450]	65 [450]	62 [425]	65 [450]	70 [485]	62 [425]	80 ksi (550 mPa)	100 [690]	95 [655]	85 [585]	75 [515]	85 [585]	63 [435]	80 [550]	80 [550]	75 [515]	100 (700)
Yield strength, [Note (1)] min, ksi [MPa]	30 [205]	35 [240]	30 [205]	35 [240]	30 [205]	37 [255]	30 [205]	37 [255]	30 [205]	30 [205]	30 [205]	28 [195]	30 [205]	30 [205]	28 [195]	35 [240]	35 [240]	28 [195]	30 [205]	25 [170]	38 ksi (260 mPa)	70 [485]	65 [450]	42.5 [295]	35 [240]	42.5 [295]	25 [170]	38 [260]	40 [275]	35 [240]	65 (450)
Elongation in 2 in. or 50 mm, [Note (2)] min, %	35.0	35.0	35.0	35.0	30.0	30.0	30.0	35.0	30.0	35.0	30.0	30.0	30.0	30.0	30.0	10.0	10.0	15.0	20.0	35.0	35	16.0	25.0	30.0	25.0	30.0	20.0	35	30.0	25	25.0
Reduction of area, min, %	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

NOTES:
(1) Determine by the 0.2% offset method.
(2) When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S2. Destruction Tests.

S5. Radiographic Inspection.

S6. Liquid Penetrant Inspection.

S10. Examination of Weld Preparation.

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 165 or Practice E 709.

S11. Post Weld Heat Treatment.

S11.1 All austenitic castings, except Grades HK, HT, and CT15C, which have been subjected to weld repairs, shall be given a post weld solution heat treatment.

SPECIFICATION FOR STEEL CASTINGS, FERRITIC AND MARTENSITIC, FOR PRESSURE CONTAINING PARTS, SUITABLE FOR LOW TEMPERATURE SERVICE

SA-352/SA-352M

(Identical with ASTM Specification A 352/A 352M-93[e1] except for editorial differences in 2.3 and 9.1) 98

1. Scope

1.1 This specification covers steel castings for valves, flanges, fittings, and other pressure-containing parts intended primarily for low-temperature service.

1.2 Several grades of ferritic steels and one grade of martensitic steel are covered. Selection of analysis will depend on design and service conditions (Note). The temperature shown is the lowest temperature at which the material ordinarily is required to meet the impact requirements of this specification (see Supplementary Requirement S22, Impact Test Temperatures). Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtainable (see Appendix X1).

Grade	Usual Minimum Testing Temperatures, °F [°C]
LCA	−25 [−32]
LCB	−50 [−46]
LCC	−50 [−46]
LC1	−75 [−59]
LC2	−100 [−73]
LC2-1	−100 [−73]
LC3	−150 [−101]
LC4	−175 [−115]
LC9	−320 [−196]
CA6NM	−100 [−73]

NOTE—This specification covers the low-temperature requirements particularly pertinent for ferritic and martensitic steels. Certain of the grades of austenitic steel castings furnished in accordance with Specification A 351/A 351M have been found suitable for low-temperature service down to −300°F [−184°C] and others down to −425°F [−254°C]. These grades may be used when impact tested in accordance with Specification A 352/A 352M with energy levels and temperatures of test mutually agreed upon between the purchaser and the manufacturer. As a guide to the selection of energy levels and testing temperatures, Appendix X1 should be consulted.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 352 and SI units for material ordered to Specification A 352M.

2. Referenced Documents

2.1 *ASTM Standards:* 98

A 351/A 351M Specification for Steel Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

E 165 Test Methods for Liquid Penetrant Inspection Method

E 709 Guide for Magnetic Particle Examination

2.2 *Manufacturers' Standardization Society of the Valve and Fittings Industry Standard:*

SP-55 Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components (Visual Method)

2.3 *ASME Standard:*

ASME Boiler and Pressure Vessel Code, Section IX, Welding and Braxing Qualifications

3. General Conditions for Delivery

98 **3.1** Material furnished to this specification shall conform to the requirements of Specification A 703/A 703M, including any supplementary requirements that are indicated on the purchaser's order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order shall include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired, including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition. It should be recognized that liquid quenching of the ferritic grades is normally required to meet the mechanical properties of heavier sections and will greatly enhance the low-temperature properties of thinner sections.

5.2 Ferritic castings shall be furnished in the normalized and tempered or liquid-quenched and tempered condition, except for Grade LC9, which shall be liquid-quenched and tempered. Castings shall be tempered at a minimum of 1100°F [590°C], except Grade LC4, which shall be 1050°F [565°C], and Grade LC9, which shall be tempered in the range of 1050 to 1175°F [565 to 635°C], followed by cooling in air or liquid.

5.3 CA6NM castings shall be heat treated by heating to 1850°F [1010°C] minimum, and air cooling to 200°F [95°C] maximum before any optional intermediate temper, but shall cool to 100°F [40°C] maximum before the final temper, which shall be between 1050 and 1150°F [565 and 620°C].

5.4 Castings shall be allowed to cool below the transformation range directly after pouring and solidification before they are reheated for normalizing or liquid quenching.

5.5 *Temperature Control*—Furnace temperature for heat treating shall be controlled by use of pyrometers.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition for the grade ordered as specified in Table 1.

7. Mechanical Requirements

7.1 *Tension Test:*

7.1.1 Tensile properties of steel used for the castings shall conform to the requirements specified in Table 1.

7.2 *Impact Test:*

7.2.1 The notched bar impact properties of the material shall be determined by testing a set of three Charpy V-notch impact specimens for each heat at one of the standard test temperatures shown in Table 1, depending on the intended service temperature (see Appendix X1). The average energy value of the three specimens shall not be less than specified, with not more than one value permitted below the average minimum specified for a single specimen.

7.2.2 The notched bar impact test shall be made in accordance with Test Methods and Definitions A 370.

7.2.3 Impact test specimens shall be machined to the form and dimensions shown in Test Methods and Definitions A 370, Type A, Charpy V-Notch specimens, Fig. 11.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 2.

8.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10 may be ordered.

8.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair by Welding

9.1 Repairs shall be made using procedures and welders as qualified under ASME Section IX.

9.2 Welding of Grade LC9 shall be accomplished using nonmagnetic filler material of AWS classification ENiCrFe-2, and shall require liquid penetrant inspection of the weld (Supplementary Requirement S6) when magnetic particle inspection (Supplementary Requirement S4) is specified for the casting.

9.3 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic tests, or on castings in which the depth of any cavity prepared for repair welding exceeds 20% of the wall thickness or 1 in. [25 mm] whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2} [65 cm^2], shall be radiographed to the same standards that are used to inspect the castings.

9.4 Castings containing any repair weld that exceeds 20% of the wall thickness, or 1 in. (25 mm), whichever is smaller, or that exceeds approximately 10 in.^{2} (65 cm^2) in area, or that was made to correct hydrostatic test defects shall be stress relieved or heat treated after welding. This mandatory stress relief or heat treatment shall be in accordance with the procedure qualification used. When stress relief is required for Grade LC9, cooling shall be in still air. 98

10. Product Marking

10.1 All marking shall be on a raised pad using low-stress stamps.

10.2 In addition to the marking required by Specification A 703/A 703M, castings that have been liquid quenched and tempered shall be marked with the letters “QT”.

TABLE 1
CHEMICAL, TENSILE, AND IMPACT REQUIREMENTS

Grade	Carbon Steel	Carbon Steel	Carbon-Manganese Steel	Carbon-Molybdenum Steel	2½% Nickel Steel	Nickel-Chromium-Molybdenum Steel	3½% Nickel Steel	4½% Nickel Steel	9% Nickel Steel	12½% Chromium, Nickel-Molybdenum Steel
Element, % (max, except where range is given)	LCA	LCB[A]	LCC	LC1	LC2	LC2-1	LC3	LC4	LC9	CA6NM
Carbon	0.25[A]	0.30	0.25[A]	0.25	0.25	0.22	0.15	0.15	0.13	0.06
Silicon	0.60	0.60	0.60	0.60	0.60	0.50	0.60	0.60	0.45	1.00
Manganese	0.70[A]	1.00	1.20[A]	0.50–0.80	0.50–0.80	0.55–0.75	0.50–0.80	0.50–0.80	0.90	1.00
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.03
Nickel	0.50[B]	0.50[B]	0.50[B]	. . .	2.00–3.00	2.50–3.50	3.00–4.00	4.00–5.00	8.50–10.0	3.5–4.5
Chromium	0.50[B]	0.50[B]	0.50[B]	. . .	. . .	1.35–1.85	. . .	. . .	0.50	11.5–14.0
Molybdenum	0.20	0.20[B]	0.20[B]	0.45–0.65	. . .	0.30–0.60	. . .	. . .	0.20	0.4–1.0
Copper	0.30[B]	0.30[B]	. . .	. . .	. . .	. . .	. . .	0.30	. . .	. . .
Vanadium	0.03[B]	0.03[B]	0.03[B]	. . .	. . .	. . .	. . .	. . .	0.03	. . .
Tensile Requirements:[C]										
Tensile strength, ksi [MPa]	60.0–85.0 [415–585]	65.0–90.0 [450–620]	70.0–95.0 [485–655]	65.0–90.0 [450–620]	70.0–95.0 [485–655]	105.0–130.0 [725–895]	70.0–95.0 [485–655]	70.0–95.0 [485–655]	85.0 [585]	110.0–135.0 [760–930]
Yield strength,[D] min, ksi [MPa]	30.0 [205]	35.0 [240]	40.0 [275]	35.0 [240]	40.0 [275]	80.0 [550]	40.0 [275]	40.0 [275]	75.0 [515]	80.0 [550]
Elongation in 2 in. or 50 mm, min, %[E]	24	24	22	24	24	18	24	24	20	15
Reduction of area, min, %	35	35	35	35	35	30	35	35	30	35
Impact Requirements Charpy V-Notch[C,F]										
Energy value, ft·lbf [J], min value for two specimens and min avg of three specimens	13 [18]	13 [18]	15 [20]	13 [18]	15 [20]	30 [41]	15 [20]	15 [20]	20 [27]	20 [27]
Energy value, ft·lbf [J], min for single specimen	10 [14]	10 [14]	12 [16]	10 [14]	12 [16]	25 [34]	12 [16]	12 [16]	15 [20]	15 [20]
Testing temperature, °F [°C]	−25 [−32]	−50 [−46]	−50 [−46]	−75 [−59]	−100 [−73]	−100 [−73]	−150 [−101]	−175 [−115]	−320 [−196]	−100 [−73]

[A] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted up to a maximum of 1.10% for LCA, 1.28% for LCB, and 1.40% for LCC.
[B] Specified Residual Elements — The total content of these elements is 1.00% maximum.
[C] See 1.2.
[D] Determine by either 0.2% offset method or 0.5% extension-under-load method.
[E] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.
[F] See Appendix X1.

TABLE 2
MINIMUM PREHEAT TEMPERATURES

Grade	Thickness, in. [mm]	Minimum Preheat Temperature, °F [°C]
LCA	all	50 [10]
LCB	all	50 [10]
LCC	all	50 [10]
LC1	over $5/8$ [15.9]	250 [120]
	$5/8$ and under	50 [10]
LC2	all	300 [150]
LC2-1	all	300 [150]
LC3	all	300 [150]
LC4	all	300 [150]
CA6NM	all	50 [10]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below together with additional supplementary requirements that are applicable only to this specification. Other supplementary requirements enumerated in A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S2. Destruction Tests

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S9. Drop Weight Tests

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 709 or Practice E 165.

S21. Heat Treatment

S21.1 Castings shall be liquid quenched and tempered.

S22. Impact Test Temperatures

98 **S22.1** When an impact test temperature other than that listed in Table 1 is used, the lowest test temperature at which the material met the impact requirements shall be stamped with low-stress stamps on a raised pad located immediately ahead of the material symbol, for example, 25 LCB ahead of the material symbol; for example, 25 LCB for +25°F (−4°C) and 025 LCB for −25°F (−32°C).

S22.2 Lateral expansion of V-notch specimens shall be measured in accordance with Section 23.2.3.1 of Test Methods A 370, and reported for information. 98

S23. Carbon Equivalent

S23.1 When specified on the order the maximum carbon equivalent shall be:

Grade	Carbon Equivalent, max
LCA	0.50
LCB	0.50
LCC	0.55

S23.2 Determine carbon equivalent *CE*, as follows: 98

$$CE = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr} + \mathrm{Mo} + \mathrm{V}}{5} + \frac{\mathrm{Ni} + \mathrm{Cu}}{15}$$

APPENDIX

(Nonmandatory Information)

X1. EXPLANATION OF THE USE OF NOTCHED BAR IMPACT TESTS IN DETERMINING THE ACCEPTABILITY OF STEELS FOR LOW-TEMPERATURE SERVICE

X1.1 Years of experience and test work have shown that some materials, particularly ferritic steels, change from tough to brittle behavior with a decrease in temperature. The transition temperatures and the levels of notch toughness vary with different materials, depending on many factors. When materials are used under conditions where brittle behavior may occur, there is danger that flaws, which would be considered nonhazardous if the material were tough, may propagate to disastrous failure of the equipment.

X1.2 Accordingly, many varieties of tests have been developed in an effort to evaluate the toughness of materials and the conditions under which they will transform from tough to brittle behavior. There are many opinions and shadings of opinion as to which test is most suitable for evaluating the suitability of materials for service at low temperatures; however, as yet, only the Charpy impact test has received sufficient general acceptance and has been used as a basis for purchasing for sufficient time to be included in ASTM standards. Furthermore, this test is required for low-temperature service vessels and piping constructed in accordance with ASME Code for Unfired Pressure Vessels and the American National Standard Code for Pressure Piping (ANSI B31), respectively. These ASTM specifications for materials for low-temperature service are primarily used in piping and pressure vessel construction that are subjected to temperatures lower than ambient; consequently, the notched bar impact test requirements are written to provide material that in quality and by its testing can be validated for use under the construction codes.

X1.3 No assurance is offered that compliance with these requirements will provide a material that will resist brittle failure under all possible conditions of service to as low as the specified impact test temperature. It may eventually be possible that other types of tests will provide greater assurance of material suitability for low-temperature services, but at this time there is insufficient knowledge for agreement and general acceptance of some test other than the Charpy impact test.

X1.4 Attention is directed to the following subjects which have a bearing on the value of Charpy impact tests:

1.4.1 Much of the original work in the field of notch toughness was done on wrought materials that had definite directional grain flow parallel to the axis of the bar, and the specimens were taken with the longitudinal axis of the specimen parallel to the axis of the bar. It has been well established that the results from impact testing of the same piece of steel may vary considerably, depending upon the orientation of the specimen to the direction of grain flow. Although it is known that specimens taken with their axis transverse to the direction of grain flow will have lower values depending on the amount of cross rolling or forging the material has received, there were insufficient test data to permit specific mandatory requirements on the impact properties of wrought materials determined in any direction other than parallel to the direction of grain flow. Except in special cases this limitation still exists.

X1.4.2 It is acknowledged that notched bar impact tests are of a qualitative rather than a quantitative nature. As yet, except possibly for ship steel, no satisfactory correlation has been possible between tests on small standardization specimens and the behavior of a structural part under any given conditions of loading in service. The required values as determined by the Charpy V-notch impact test are arbitrary values which can be met by carbon and low-alloy constructional steels when tested at temperatures above that where their behavior changes from tough to brittle as judged by this test. The acceptability of this dividing line seems to be justified by service experience on carbon and certain low-alloy steels.

X1.4.3 The literature shows that notched bar impact strengths in constructional steels differ widely in accordance with many variables. Consequently, there is bound to be some discrepancy between an individual test bar and the entire part that it represents. No system of test

bar selection can guarantee that every sample would meet minimum requirements. Test bar selection must be a compromise to generally represent the product.

X1.4.4 The committees responsible for these material specifications have had as an objective the selection of test specimens that will represent the properties of the materials, in the form in which they will be used. However, accomplishment of this objective has only partially been realized. At this time it is impossible to select samples for testing that will represent all parts and sizes of the product involved. Particularly in ferritic steels, it is impractical to remove the test bars from heavy sections over about 4 in. [100 mm] and expect them to show results as high as tests from light sections of the same material. The practical commercial limits on the amount of testing possible, as well as limits to knowledge of what results may be expected from testing in non-standard locations, have been considered in drafting these specifications. With time and increased knowledge, it may be possible to require more representative testing.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, 9 PERCENT NICKEL, DOUBLE-NORMALIZED AND TEMPERED

SA-353/SA-353M

(Identical with ASTM Specification A 353/A 353M-93.)

1. Scope

1.1 This specification covers 9% nickel steel plates, double-normalized and tempered, intended particularly for welded pressure vessels for cryogenic service.

1.2 Plates produced under this specification are subject to impact testing at −320°F [−195°C] or at such other temperatures as are agreed upon.

1.3 The maximum thickness of plates is limited only by the capacity of the material to meet the specific mechanical property requirements; however, current mill practice normally limits this material to 2 in. [50 mm] max.

1.4 This material is susceptible to magnetization. Use of magnets in handling after heat treatment should be avoided if residual magnetism would be detrimental to subsequent fabrication or service.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.1 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be heat treated in accordance with 5.2. Shell plates and other parts, including heads and reinforcing pads, which are heated for forming, shall be heat treated after forming in accordance with 5.2.

5.2 *Heat Treatment Procedure:*

5.2.1 *First Normalizing Treatment* — Heat the plate to a uniform temperature of 1650 ± 25°F [900 ± 15°C], hold at this temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and cool in air.

5.2.2 *Second Normalizing Treatment* — Reheat the plate to a uniform temperature of 1450 ± 25°F [790 ± 15°C], hold at this temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and cool in air.

5.2.3 *Tempering Treatment* — Reheat the plate to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C], hold at this temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and cool in air or water quench at a rate not less than 300°F/h [165°C/h].

5.2.4 If hot forming is performed after heating to a temperature within the range from 1650 to 1750°F [900 to 955°C] the first normalizing treatment (5.2.1) may be omitted.

5.2.5 When the plates are heat treated by the fabricator, it shall be his responsibility to apply the proper heat treatment and to conduct tests he deems necessary to assure that the specified properties are attained.

6. Chemical Requirements

6.1 The steel shall conform to the chemical composition requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements* — The material as represented by the tension-test specimens shall conform to the requirements specified in Table 2.

7.1.1 Upon agreement between the purchaser and the manufacturer, yield strength may be determined by the extension under load method, using 0.005 in./in. [0.005 mm/mm] total extension.

7.1.2 For nominal plate thicknesses of $\frac{3}{4}$ in. [20 mm] and under, the $1\frac{1}{2}$ in. [40 mm] wide rectangular specimen may be used for the tension test and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and shows the greatest elongation.

7.1.3 One tension test shall be taken from each plate as heat treated.

7.2 *Impact Test Requirements:*

7.2.1 Charpy V-notch impact tests shall be made in accordance with Specification A 20/A 20M.

7.2.2 The longitudinal axis of the test specimens shall be transverse to the final rolling direction of the plate.

7.2.3 Unless otherwise agreed, tests shall be conducted at −320°F [−195°C].

7.2.4 Each test specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. [0.381 mm].

8. Finish

8.1 Because retained scale may mask surface imperfections, as well as mar the plate surface, plates shall be descaled by the producer after heat treatment. In the case of material to be heat-treated by the purchaser, the plates shall be descaled by the producer prior to shipment.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %
Carbon, max[A]	0.13
Manganese, max	
Heat analysis	0.90
Product analysis	0.98
Phosphorus, max[A]	0.035
Sulfur, max[A]	0.035
Silicon:	
Heat analysis	0.15–0.40
Product analysis	0.13–0.45
Nickel:	
Heat analysis	8.50–9.50
Product analysis	8.40–9.60

[A] Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

Tensile strength, ksi [MPa]	100–120 [690–825]
Yield strength (0.2% offset), min, ksi [MPa][A]	75 [515]
Elongation in 2 in. [50 mm], min, %	20.0

[A] See 7.1.1.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.
A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S6. Drop Weight Test,

S8. Ultrasonic Examination in Accordance with Specification A 435/A 435M,

S11. Ultrasonic Examination in Accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in Accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below are additional optional Supplementary Requirements S55 and S56 which are suitable for this specification.

S55. Longitudinal Charpy Impact Energy Absorption Requirement

S55.1 The longitudinal Charpy V-notch impact properties shall not be less than 25 ft·lbf [34 J] at the specified temperature.

S55.2 Each impact-test value shall constitute the average value of three specimens, with not more than one value below the specified minimum value of 25 ft·lbf [34 J], but in no case below 20 ft·lbf [27 J] for full-size specimens.

S56. Transverse Charpy Impact Energy Absorption Requirement

S56.1 The transverse Charpy V-notch impact properties shall not be less than 20 ft·lbf [27 J] at the specified temperature.

S45.2 Each impact-test value shall constitute the average value of three specimens, with not more than one value below the specified minimum value of 20 ft·lbf [27 J] but in no case below 15 ft·lbf [20 J] for full-size specimens.

SPECIFICATION FOR QUENCHED AND TEMPERED ALLOY STEEL BOLTS, STUDS, AND OTHER EXTERNALLY THREADED FASTENERS

SA-354

(Identical with ASTM Specification A 354-95.) 98

1. Scope

1.1 This specification covers the chemical and mechanical requirements of quenched and tempered alloy steel bolts, studs, and other externally threaded fasteners 4 in. and under in diameter for application at normal atmospheric temperatures, where high strength is required and for limited application at elevated temperature (Note 1). Any alloy steel capable of meeting the minimum mechanical and chemical properties set forth in this specification may be used.

NOTE 1 — For bolts, studs, or other externally threaded fasteners, to be used at elevated temperatures, refer to Specification A 193/A 193M.

1.2 Two levels of bolting strength are covered, designated Grades BC and BD. Selection will depend upon design and the stresses and service for which the product is to be used.

NOTE 2 — Quenched and tempered alloy steel bolts for structural steel joints up through $1\frac{1}{2}$ in. in diameter are covered in Specification A 490. Alloy steel bolts, studs, and other externally threaded fasteners (that is, heavy hex-structural bolts over $1\frac{1}{2}$ in., hex bolts, and anchor bolts, and countersunk bolts) exhibiting similar mechanical properties to bolts conforming to Specification A 490 shall be covered by Grade BD of this specification.

When bolts of Grade BD of this specification are considered for pretensioned applications in excess of 50% of the bolt tensile strength, the additional requirements of head size, maximum tensile strength, nut size and strength, washer hardness, tests, and inspections contained in Specification A 490 should be carefully considered.

1.3 Nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut for each grade of fastener shall be as follows:

Grade of Fastener and Surface Finish	Nut Grade and Style[A]
BC, plain (or with a coating of insufficient thickness to require over-tapped nuts)	C, heavy hex
BC, zinc-coated (or with a coating thickness requiring over-tapped nuts)	DH, heavy hex
BD, all finishes	DH, heavy hex

[A] Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nut are suitable.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service

A 490 Specification for Heat-Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength

A 563 Specification for Carbon and Alloy Steel Nuts

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

D 3951 Practice for Commercial Packaging

F 436 Specification for Hardened Steel Washers

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

2.2 *ANSI/ASME Standards:*
B1.1 Unified Screw Threads
B18.2.1 Square and Hex Bolts and Screws, Inch Series

2.3 *Military Standard:*
MIL-STD 105 Single Sampling Plan for Normal Inspection

3. Ordering Information

3.1 Orders for bolts and studs (including nuts and accessories) under this specification shall include the following:

3.1.1 ASTM designation and year of issue,

3.1.2 Name of product (that is, bolt or stud),

3.1.3 Grade (that is, BC or BD),

3.1.4 Quantities (number of pieces by size, including nuts),

3.1.5 Size and length,

3.1.6 Washers — Specify quantity and size (separate from bolts) (4.3),

3.1.7 *Zinc Coating* — When zinc-coated Grade BC fasteners are required, specify the zinc-coating process required, for example hot-dip, mechanically deposited, or no preference (see 4.4),

3.1.8 *Other Finishes* — Specify other protective finish, if required,

3.1.9 Specify if inspection at point of manufacture is required,

3.1.10 Specify if Certification is required (Section 14), and

3.1.11 Specify additional testing (Section 9) or special requirements.

4. Materials and Manufacture

4.1 The steel shall be made by the open-hearth, electric-furnace, or basic-oxygen process.

4.2 All fasteners shall be heat-treated. At the option of the manufacturer, heat treatment may be performed on the raw material, during the manufacturing operations, or after final machining. Heat treatment shall consist of quenching in a liquid medium (except Grade BD must be quenched in oil) from above the transformation temperature and then temperating by reheating to a temperature of not less than 800°F (427°C) for Grade BC and for Grade BD.

4.3 When used, suitable hardened washers shall be quenched and tempered (non-carburized) in accordance with Specification F 436.

4.4 *Zinc Coatings, Hot-Dip and Mechanically Deposited:*

4.4.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot-dip, mechanically deposited, or no preference.

4.4.2 When "hot-dip" is specified, the fasteners shall be zinc coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153.

4.4.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical-deposition process in accordance with the requirements of Class 50 of Specification B 695.

4.4.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier's option is limited to one process per item with no mixed processes in a lot.

NOTE 3 — When the intended application requires that assembled tension exceeds 50% of minimum bolt proof load, an anti-galling lubricant may be needed. Application of such a lubricant to nuts and a test of the lubricant efficiency are provided in Supplementary Requirement S1 of Specification A 563 and should be specified when required.

4.5 Zinc-coated bolts and nuts shall be shipped in the same container unless specifically requested otherwise by the purchaser.

NOTE 4 — Research conducted on bolts of similar material and manufacture indicates that hydrogen-stress cracking or stress cracking corrosion may occur on hot-dip galvanized Grade BD bolts.

5. Chemical Composition

5.1 All fasteners shall be made from alloy steel conforming to the chemical composition requirements in accordance with Table 1. The steel shall contain sufficient alloying elements to qualify it as an alloy steel.

NOTE 5 — Steel is considered to be alloy, by the American Iron and Steel Institute, when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 %; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

5.2 Product analysis may be made by the purchaser from finished material representing each lot of fasteners. The chemical composition thus determined shall conform to the requirements given in Table 1. Choice of alloy steel composition necessary to assure meeting the specified mechanical requirements shall be made by the manufacturer and shall be reported to the purchaser for information purposes only.

5.3 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5.4 Chemical analyses shall be performed in accordance with Test Methods A 751.

6. Mechanical Properties

6.1 Fasteners shall not exceed the maximum hardness specified in Table 2. Fasteners less than three diameters in length and studs less than four diameters in length shall have hardness values not less than the minimum nor more than the maximum hardness limits required in Table 2, as hardness is the only requirement.

6.2 Fasteners 1⅜ in. in diameter or less for Grade BC and 1¼ in. in diameter or less for Grade BD, other than those excepted in 6.1, shall be tested full size and shall conform to the tensile strength and either the proof load or the yield strength requirements in accordance with Table 3.

6.3 Fasteners larger than 1⅜ in. in diameter for Grade BC and fasteners larger than 1¼ in. in diameter for Grade BD, other than those excepted in 6.1, shall preferably be tested full size and when so tested, shall conform to the tensile strength and either the proof load or yield strength requirements specified in Table 3a or 3b. When equipment of sufficient capacity for full-size testing is not available, or when the length of the fastener makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements of Table 4. In the event that fasteners are tested by both full-size and by the machined test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

6.4 For fasteners on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low readings of hardness tests.

7. Dimensions

7.1 *Bolts* — Unless otherwise specified, the bolts shall be Hex Head with dimensions conforming to the latest issue of ANSI/ASME B18.2.1.

7.2 *Studs* — Studs shall have dimensions conforming to those specified by the purchaser.

7.3 *Threads:*

7.3.1 Unless otherwise specified, threads shall be the Unified National Coarse Thread Series as specified in ANSI B1.1, and shall have Class 2A tolerances.

7.3.2 When specified, threads shall be the Unified National Fine Thread Series, 8-Pitch Thread Series for sizes over 1 in. or 14-Pitch UNS on 1 in. size as specified in ANSI B1.1 and shall have Class 2A tolerances.

7.3.3 Unless otherwise specified, bolts and studs to be used with nuts or tapped holes that have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot dip or mechanically deposited zinc coating. After zinc coating, the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

Diameter, in.	Oversize Limit, in. (mm)[A]
¼	0.016
5⁄16, ⅜	0.017
7⁄16, ½	0.018
9⁄16, ¾ incl	0.020
⅞	0.022
1.0 to 1¼ incl	0.024
1⅜, 1½	0.027
1¾ to 4.0 incl	0.050

[A] These values are the same as the overtapping required for zinc-coated nuts in Specification A 563.

7.3.4 The gaging limit for bolts shall be verified during manufacture or use by assembly of a nut tapped as nearly as practical to the amount oversize shown. In case of dispute, a calibrated thread ring gage of that same size (Class X tolerance, gage tolerance plus) is to be used. Assembly of the gage, or the nut described, must be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, are to be performed at the frequency and quality in accordance with Table 5.

8. Workmanship

8.1 Surface discontinuity limits shall be in accordance with Specification F 788/F 788M.

9. Number of Mechanical Tests

9.1 *Testing Responsibility:*

9.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 9.2 through 9.6.

9.1.2 When fasteners are furnished by a source other than the manufacturer, the responsible party as defined in 12.1 shall be responsible for ensuring that all tests have been performed and the fasteners comply with the requirements of this specification.

9.2 *Purpose of Lot Inspection*—The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

9.3 *Lot Processing*—All fasteners shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each lot of fasteners from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

9.4 *Lot Definition*—A lot is a quantity of a uniquely identified fastener product of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and heat treatment lot and processed at one time, by the same process, in the same manner so that statistical sampling is valid. The identity of the lot is maintained throughout all subsequent operations and packaging.

9.5 *Number of Tests*—The number of tests from each lot for each required property shall be in accordance with Table 6.

9.6 If any test specimen shows defective machining it may be discarded and another specimen substituted.

10. Test Methods

10.1 Test methods shall be conducted in accordance with Test Methods F 606.

10.2 Proof load, rather than yield strength determination is preferred and shall be the arbitration method for fasteners $1\frac{1}{4}$ in. and under in diameter.

10.3 Hexagon bolts shall be tested by the wedge tension method. Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body.

10.3.1 At the option of the manufacturer, the yield strength test (Method 2, Yield Strength paragraph of Test Method F 606) and the wedge tension test (Wedge Tension Testing of Full-Size Product paragraph, both from the Test Method section of Test Method F 606) may be accomplished concurrently to satisfy 10.2 and 10.3.

10.4 Studs and bolts other than those in 10.3 shall be tested by the axial tension method.

10.4.1 At the option of the manufacturer, the yield strength test and the axial tension test may be accomplished concurrently to satisfy 10.2 and 10.4.

10.5 The speed of testing determined with a free running crosshead shall be a maximum of $\frac{1}{8}$ in. (3.2 mm)/min for the bolt proof load (or yield strength) determination and a maximum of 1 in. (25.4 m)/min for the tensile strength determination.

11. Inspection

11.1 If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry and contract or purchase order.

11.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

12. Responsibility

12.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. Certification

14.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party in accordance with Section 12, shall furnish the purchaser a test report which includes the following:

14.1.1 Product description, grade, quantity, ASTM Specification Number and issue date,

14.1.2 Alloy grade (AISI, SAE, UNS, etc.), heat analysis, and heat number, and type of quench,

14.1.3 Results of hardness, tensile, and proof load tests, as applicable,

14.1.4 Statement of compliance to Protective Coating Specification (if applicable) and baking time and temperature. If not baked state "Not baked",

14.1.5 Statement of compliance with the surface discontinuity requirements of Specification F 788/F 788M,

14.1.6 Statement of compliance dimensionally,

14.1.7 Report, describe, or illustrate manufacturer's markings and their location,

14.1.8 Lot number, purchase order number, and date shipped,

14.1.9 Country of origin, and

14.1.10 Title and signature of the individual assigned certification responsibility by the company officers, with complete mailing address.

14.2 Failure to include all the required information on the test report shall be cause for rejection.

15. Product Marking

15.1 All products shall be marked with the manufacturer's or private label distributor's identification symbol, as appropriate.

15.2 Grade BC products shall be marked with the grade marking "BC."

15.3 Grade BD bolts $\frac{1}{4}$ to $2\frac{1}{2}$ in. diameter shall be marked with six radial lines 60° apart; and, in addition may be marked with the grade symbol "BD." Grade BD bolts over $2\frac{1}{2}$ in. diameter, and all sizes of all other Grade BD products, shall be marked with the Grade Symbol "BD."

15.4 Where studs have both coarse and fine threads, all marking shall appear on the coarse thread end or, if preferred, the manufacturer's or private label distributor's identification shall appear on the fine thread end and the grade marking on the coarse thread end.

15.5 Continuous thread studs may be marked on either end.

15.6 Bolt heads shall be marked on the top of the head.

15.7 All markings may be raised or depressed at the manufacturer's option.

15.8 Grade and manufacturer's or private label distributor's identification shall be separate and distinct. The two identifications shall preferably be in different locations and when on the same level shall be separated by at least two spaces.

16. Packaging and Package Marking

16.1 *Packaging:*

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 *Package Marking:*

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

16.2.1.1 ASTM designation and grade,

16.2.1.2 Size,

16.2.1.3 Name and brand or trademark of the manufacturer,

16.2.1.4 Number of pieces,

16.2.1.5 Purchase order number, and

16.2.1.6 Country of origin.

17. Keywords

17.1 alloy steel; bolts; steel; studs

TABLE 1
CHEMICAL REQUIREMENTS

Element	Heat Analysis, %	Product Analysis, %
Carbon:		
For sizes through 1½ in.	0.30 to 0.53	0.28 to 0.55
For sizes larger than 1½ in.	0.35 to 0.53	0.33 to 0.55
Phosphorus, max	0.035	0.040
Sulfur, max	0.040	0.045

TABLE 2
HARDNESS REQUIREMENTS FOR FULL-SIZE FASTENERS

		Hardness			
		Brinell		Rockwell C	
Size, in.	Grade	Min	Max	Min	Max
¼ to 2½	BC	255	331	26	36
Over 2½	BC	235	311	22	33
¼ to 2½	BD	311	363	33	39
Over 2½	BD	293	363	31	39

TABLE 3A
TENSILE REQUIREMENTS FOR ALL FULL-SIZE FASTENERS — INCH-POUND UNITS

			Grade BC			Grad BD		
Bolt Size, in.	Threads per Inch	Stress Area,[A] in.^{2}	Tensile Strength, min, lbf[B]	Proof Load min, lbf[C]	Yield Strength 0.2% offset), min, lbf[D]	Tensile Strength, min, lbf[E]	Proof Load min, lbf[F]	Yield Strength (0.2% offset), min, lbf[G]
1	2	3	4	5	6	7	8	9
1/4	20	0.0318	4 000	3 350	3 450	4 750	3 800	4 100
1/4	28	0.0364	4 350	3 100	3 950	5 450	4 350	4 700
5/16	18	0.0524	6 550	5 500	5 700	7 850	6 300	6 800
5/16	24	0.0580	6 950	4 900	6 300	8 700	6 950	7 500
3/8	16	0.0775	9 700	8 150	8 450	11 650	9 300	10 075
3/8	24	0.0878	10 500	7 450	9 550	13 200	10 500	11 400
7/16	14	0.1063	13 300	11 150	11 600	15 950	12 750	13 850
7/16	20	0.1187	14 200	10 100	12 900	17 800	14 200	15 400
1/2	13	0.1419	17 750	14 900	15 450	21 300	17 050	18 500
1/2	20	0.1599	19 200	13 600	17 400	24 000	19 200	20 750
9/16	12	0.182	22 750	19 100	19 850	27 300	21 850	23 600
9/16	18	0.203	24 400	17 300	22 100	30 400	24 400	26 350
5/8	11	0.226	28 250	23 750	24 650	33 900	27 100	29 400
5/8	18	0.256	30 700	21 800	27 900	38 400	30 700	33 250
3/4	10	0.334	41 750	35 050	36 400	50 100	40 100	43 400
3/4	16	0.373	44 800	31 700	40 650	56 000	44 800	48 450
7/8	9	0.462	57 750	48 500	50 350	69 300	55 450	60 100
7/8	14	0.509	61 100	43 300	55 450	76 400	61 100	66 150
1	8	0.606	75 750	63 650	66 050	90 900	72 700	78 800
1	12	0.663	79 600	56 400	72 250	99 400	79 600	86 150
1	14 UNS	0.679	81 500	57 700	74 400	101 900	81 500	88 250
1 1/8	7	0.763	95 400	80 100	83 150	114 450	91 550	99 200
1 1/8	8	0.790	98 750	82 950	86 200	118 500	94 800	102 700
1 1/8	12	0.856	89 900	63 300	93 300	128 400	102 700	111 250
1 1/4	7	0.969	121 150	101 750	105 600	145 350	116 300	126 000
1 1/4	8	1.000	125 000	105 000	109 000	150 000	120 000	130 000
1 1/4	12	1.073	112 700	79 400	116 950	161 000	128 800	139 450
1 3/8	6	1.155	144 400	121 300	125 900	173 250	138 600	150 200
1 3/8	8	1.233	154 150	129 450	134 400	185 000	148 000	160 300
1 3/8	12	1.315	138 100	97 300	143 300	197 200	157 800	170 950
1 1/2	6	1.405	175 650	147 550	153 150	210 750	168 600	182 500
1 1/2	8	1.492	186 500	156 650	162 250	233 800	175 050	194 000
1 1/2	12	1.581	166 000	117 000	172 300	237 200	189 700	205 500
1 3/4	5	1.90	237 500	199 500	207 100	285 000	228 000	247 000
1 3/4	8	2.08	260 000	218 400	226 700	312 000	249 600	270 000
2	4 1/2	2.50	312 500	262 500	272 500	375 000	300 000	325 000
2	8	2.77	346 250	290 850	301 950	415 000	332 400	360 000
2 1/4	4 1/2	3.25	406 250	341 250	354 250	487 000	390 000	422 500
2 1/4	8	3.56	445 000	373 800	388 050	534 000	422 200	462 800
2 1/2	4	4.00	500 000	420 000	436 000	600 000	480 000	520 000
2 1/2	8	4.44	550 000	466 200	483 950	666 000	532 800	577 200
2 3/4	4	4.93	566 950	468 350	488 050	690 200	517 650	566 950
2 3/4	8	5.43	624 450	515 850	537 550	750 200	570 150	624 450
3	4	5.97	686 550	567 150	591 050	835 800	626 850	686 550
3	8	6.51	748 650	618 450	644 500	911 400	683 550	748 650
3 1/4	4	7.10	816 500	674 500	702 900	994 000	745 500	816 500
3 1/4	8	7.69	884 350	730 550	761 300	1 076 600	807 650	884 350
3 1/2	4	8.33	957 950	791 350	824 650	1 166 200	874 650	957 950
3 1/2	8	8.96	1 030 400	851 200	887 050	1 254 400	940 800	1 030 400
3 3/4	4	9.66	1 110 900	917 700	956 350	1 352 400	1 014 300	1 110 900
3 3/4	8	10.34	1 199 100	983 300	1 023 650	1 447 600	1 085 700	1 189 100
4	4	11.08	1 274 200	1 052 600	1 096 900	1 551 200	1 163 400	1 274 200
4	8	11.81	1 358 200	1 122 000	1 169 200	1 653 400	1 240 050	1 358 150

[A] Stress Area, in.^{2} = $0.7854\,[D - 0.9743/n]^2$ where D = nominal diameter in inch and n = threads per inch.
[B] Based on 125 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 115 000 psi for sizes over 2 1/2 to 4 in., inclusive.
[C] Based on 105 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 95 000 psi for sizes over 2 1/2 to 4 in., inclusive.
[D] Based on 109 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 99 000 psi for sizes over 2 1/2 to 4 in., inclusive.
[E] Based on 150 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 140 000 psi for sizes over 2 1/2 to 4 in., inclusive.
[F] Based on 120 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 105 000 psi for sizes over 2 1/2 to 4 in., inclusive.
[G] Based on 130 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 115 000 psi for sizes over 2 1/2 to 4 in., inclusive.

TABLE 3B
TENSILE REQUIREMENTS FOR ALL FULL-SIZE FASTENERS — SI UNITS

			Grade BC			Grade BD		
Bolt Size, in.	Threads per Inch	Stress Area,[A] mm²	Tensile Strength, min, kN[B]	Proof Load min, kN[C]	Yield Strength (0.2% offset), min, kN[D]	Tensile Strength, min, kN[E]	Proof Load min, kN[F]	Yield Strength (0.2% offset), min, kN[G]
1	2	3	4	5	6	7	8	9
1/4	20	20.5	17.7	14.9	15.4	21.2	17.0	18.4
1/4	28	23.5	20.2	17.0	17.7	24.3	19.4	21.1
5/16	18	33.8	29.1	24.5	25.4	35.0	28.0	30.3
5/16	24	37.4	32.2	27.1	28.1	38.7	30.9	33.5
3/8	16	50.0	43.1	36.2	37.6	51.7	41.4	44.8
3/8	24	56.6	48.8	41.0	42.6	58.5	46.8	50.7
7/16	14	68.6	59.1	49.6	51.5	70.9	56.7	61.5
7/16	20	76.6	66.0	55.5	57.6	79.2	63.3	68.6
1/2	13	91.5	78.9	66.3	68.8	94.7	75.7	82.1
1/2	20	103	88.8	74.6	77.5	106.5	85.2	92.3
9/16	12	111	101.2	85.0	88.2	121.4	97.1	105.2
9/16	18	131	112.9	94.8	98.5	135.4	108.3	117.4
5/8	11	146	125.7	105.6	109.6	150.8	120.6	130.7
5/8	18	165	142.2	119.5	124.1	170.6	136.5	147.8
3/4	10	215	185.7	156.0	161.9	222.9	178.3	193.1
3/4	16	241	207.7	174.5	181.2	249.2	199.3	215.9
7/8	9	296	256.9	215.8	224.0	308.3	246.6	267.2
7/8	14	328	282.3	237.5	246.6	339.2	271.3	293.9
1	8	391	337.0	283.0	293.8	404.3	323.5	350.4
1	12	428	368.9	309.9	321.8	442.6	354.0	383.5
1	14 UNS	438	377.6	317.1	329.4	452.9	362.2	392.4
1 1/8	7	492	424.2	356.4	369.9	509.1	407.3	441.2
1 1/8	8	510	439.3	369.0	383.0	527.1	421.7	456.8
1 1/8	12	552	475.8	399.6	415.1	570.8	456.5	494.6
1 1/4	7	625	538.8	452.6	469.8	646.5	517.2	560.3
1 1/4	8	645	556.0	467.1	484.9	667.2	533.8	578.3
1 1/4	12	692	596.5	501.0	520.4	715.5	572.3	620.0
1 3/8	6	745	642.2	539.5	560.0	770.7	616.5	667.9
1 3/8	8	795	685.6	575.9	597.8	822.7	658.2	713.0
1 3/8	12	848	731.0	614.0	637.7	876.8	701.3	759.8
1 1/2	6	906	781.2	656.2	681.2	937.5	750.0	812.5
1 1/2	8	963	829.6	696.9	723.4	995.5	796.4	862.8
1 1/2	12	1020	879.2	738.5	767.0	1054.7	843.5	913.9
1 3/4	5	1226	1056	887.4	921.2	1268	1014	1099
1 3/4	8	1342	1157	971.5	1009	1388	1110	1203
2	4 1/2	1613	1390	1168	1212	1668	1334	1446
2	8	1787	1540	1294	1343	1848	1479	1602
2 1/4	4 1/2	2097	1807	1518	1576	2169	1735	1879
2 1/4	8	2297	1979	1663	1726	2375	1900	2059
2 1/2	4	2581	2224	1868	1939	2669	2135	2313
2 1/2	8	2865	2469	2074	2153	2963	2370	2568
2 3/4	4	3181	2741	2303	2390	3289	2632	2851
2 3/4	8	3503	3019	2536	2633	3623	2898	3140
3	4	3852	3319	2788	2895	3983	3187	3452
3	8	4200	3620	3041	3156	4344	3475	3765
3 1/4	4	4581	3948	3316	3442	4737	3790	4106
3 1/4	8	4961	4276	3592	3729	5131	4105	4447
3 1/2	4	5374	4632	3891	4039	5558	4446	4817
3 1/2	8	5781	4982	4185	4344	5978	4783	5181
3 3/4	4	6232	5371	4512	4684	6445	5156	5586
3 3/4	8	6671	5749	4829	5013	6899	5519	5979
4	4	7148	6161	5175	5372	7393	5914	6407
4	8	7619	6567	5516	5726	7880	6304	6829

[A] Stress Area, mm² = 0.7854 (D − 0.9382 P)², where D = nominal product size, mm, and P = thread pitch, mm.
[B] Based on 862 MPa for sizes 1/4 to 2 1/2 in., inclusive, and on 793 MPa for sizes over 2 1/2 to 4 in., inclusive.
[C] Based on 724 MPa for sizes 1/4 to 2 1/2 in., inclusive, and on 655 MPa for sizes over 2 1/2 to 4 in., inclusive.
[D] Based on 752 MPa for sizes 1/4 to 2 1/2 in., inclusive, and on 683 MPa for sizes over 2 1/2 to 4 in., inclusive.
[E] Based on 1034 MPa for sizes 1/4 to 2 1/2 in., inclusive, and on 965 MPa for sizes over 2 1/2 to 4 in., inclusive.
[F] Based on 827 MPa for sizes 1/4 to 2 1/2 in., inclusive, and on 724 MPa for sizes over 2 1/2 to 4 in., inclusive.
[G] Based on 896 MPa for sizes 1/4 to 2 1/2 in., inclusive, and on 793 MPa for sizes over 2 1/2 to 4 in., inclusive.

TABLE 4
MECHANICAL REQUIREMENTS FOR MACHINED SPECIMENS

Grade	Size, in.	Tensile Strength min, psi (MPa)	Yield Strength (0.2% offset), min, psi (MPa)	Elongation in 2 in. or 50 mm, min, %	Reduction of Area min, %
BC	$\frac{1}{4}$ to $2\frac{1}{2}$, incl	125 000 (862)	109 000 (752)	16	50
BC	Over $2\frac{1}{2}$	115 000 (793)	99 000 (683)	16	45
BD	$\frac{1}{4}$ to $2\frac{1}{2}$, incl	150 000 (1034)	130 000 (896)	14	40
BD	Over $2\frac{1}{2}$	140 000 (965)	115 000 (793)	14	40

TABLE 5
SAMPLE SIZES AND ACCEPTANCE NUMBERS FOR INSPECTION OF HOT-DIP OR MECHANICALLY DEPOSITED ZINC-COATED THREADS

Lot Size	Sample Size[A,B]	Acceptance Number[A]
2 to 90	13	1
91 to 150	20	2
151 to 280	32	3
281 to 500	50	5
501 to 1 200	80	7
1 201 to 3 200	125	10
3 201 to 10 000	200	14
10 001 and over	315	21

[A] Sample sizes of acceptance numbers are extracted from "Single Sampling Plan for Normal Inspection" Table IIA, MIL-STD-105.
[B] Inspect all bolts in the lot if the lot size is less than the sample size.

TABLE 6
SAMPLE SIZES AND ACCEPTANCE NUMBERS FOR INSPECTION OF MECHANICAL AND DIMENSIONAL REQUIREMENTS

Lot Size	Sample Size	Acceptance Number	Rejection Number
25 and less	2	0	1
26 to 150	3	0	1
151 to 1 200	5	0	1
1 201 to 35 000	8	0	1
35 000 to 150 000	13	0	1
150 000 and over	20	0	1

SUPPLEMENTARY REQUIREMENT

S1. Marking

S1.1 Studs that are continuously threaded with the same class of thread shall be marked on each end with the marking in accordance with Section 15.

S1.2 Marking small sizes (customarily less than 0.375 in. (9.525 mm) may not be practical. Consult the producer for the minimum size that can be marked.

SPECIFICATION FOR ELECTRIC-FUSION-WELDED AUSTENITIC CHROMIUM-NICKEL ALLOY STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

SA-358/SA-358M

(Identical to ASTM Specification A 358/A 358M-95a[E1] except for clarified heat treatment requirements in 5.3.1, editorial difference in Table 1, and following additional requirements.) **98**

All products furnished under this SA specification are intended for application under the rules of Section III or Section VIII-1 of the ASME Boiler and Pressure Vessel Code. Manufacture of such products is limited to manufacturers who hold the appropriate ASME Certificate of Authorization and Code Symbol Stamp. In addition to conforming to this specification, the manufacturer shall meet all applicable requirements of Section III or Section VIII-1 if applicable of the Code. The plate used to fabricate the pipe shall conform to SA-240. The joints shall be full penetration butt welds as obtained by double welding or by other means which will obtain the same quality of deposited and weld metal on the inside and outside. Welds using metal backing strips which remain in place are excluded. The product is subject to all requirements of Section III or Section VIII-1 if applicable of the Code including welding, heat treatment, nondestructive examination, authorized inspection at the point of manufacture, and application of the Code Symbol Stamp.

The applicable ASME Partial Data Report Form signed by an Authorized Inspector and a certified mill test report shall be furnished for each lot of pipe. The term "lot" applies to all pipe of the same mill heat of material and wall thickness which is heat treated in one furnace charge. For pipe that is not heat treated, or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft (61 m) or fraction thereof of all pipe of the same mill heat material and wall thickness subjected to the same heat treatment. For pipe that is heat treated in a batch-type furnace that is automatically controlled within a 50°F range and is equipped with recording pyrometers so that the heating records are available, a lot may be defined the same as for continuous furnaces. Each length of pipe shall be marked in such a manner as to identify each such piece with the lot and the certified mill test report.

1. Scope

1.1 This specification covers electric-fusion-welded austenitic chromium-nickel alloy steel pipe suitable for corrosive or high-temperature service, or both.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.2 This specification covers nineteen grades of alloy steel as indicated in Table 1 The selection of the proper alloy and requirements for heat treatment shall be at the discretion of the purchaser, dependent on the service conditions to be encountered.

1.3 Five classes of pipe are covered as follows:

1.3.1 *Class 1* — Pipe shall be double welded by processes employing filler metal in all passes and shall be completely radiographed.

1.3.2 *Class 2* — Pipe shall be double welded by processes employing filler metal in all passes. No radiography is required.

1.3.3 *Class 3* — Pipe shall be single welded by processes employing filler metal in all passes and shall be completely radiographed.

1.3.4 *Class 4* — Same as Class 3 except that the weld pass exposed to the inside pipe surface may be made without the addition of filler metal (see 5.2.2.1 and 5.2.2.2).

1.3.5 *Class 5* — Pipe shall be double welded by processes employing filler metal in all passes and shall be spot radiographed.

1.4 Supplementary requirements covering provisions ranging from additional testing to formalized procedures for manufacturing practice are provided. Supplementary

Requirements S1 through S6 are included as options to be specified when desired.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 240 Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

2.2 *ASME Boiler and Pressure Vessel Code:*

Section I, Welding and Brazing Qualifications

Section IX, Welding Qualifications

2.3 *AWS Specifications:*

A 5.22 Flux Cored Arc Welding

A 5.30 Consumable Weld Inserts for Gas Tungsten Arc Welding

A 5.4 Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes

A 5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes

A 5.11 Nickel and Nickel-Alloy Covered Welding Electrodes

A 5.14 Nickel and Nickel-Alloy Bare Welding Rods and Electrodes

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, meters, or number of lengths),

3.1.2 Name of material (electric-fusion-welded pipe),

3.1.3 Grade (Table 1),

3.1.4 Class (see 1.3),

3.1.5 Size (outside diameter and nominal wall thickness),

3.1.6 Length (specific or random),

3.1.7 End finish (Section on Ends of Specification A 530/A 530M),

3.1.8 Authorization for repair of plate defects by welding and subsequent heat treatment without prior approval if such is intended (see 8.3),

3.1.9 Specification designation,

3.1.10 Special requirements,

3.1.11 Statement invoking requirements of 16.4 if such is intended.

3.1.12 Circumferential weld permissibility (see Section 15),

3.1.13 Supplementary Requirements (S1 through S6),

3.1.14 Applicable ASME Code if known,

3.1.15 For ASME Code Section III applications, the service classification intended, and

3.1.16 Certification requirements (see Section on Certification of Specification A 530/A 530M).

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

4.2 The following sections only of Specification A 530/A 530M apply: 3, 4, 6, 17, 18, 20, 21, 22, 23, and 24.

5. Materials and Manufacture

5.1 *Materials:*

5.1.1 The steel plate material shall conform to the requirements of one of the grades of Specification A 240, listed in Table 1, except as provided in 5.3.2.3

5.2 *Welding:*

5.2.1 The joints shall be full penetration double-welded or single-welded butt joints employing fusion

welding processes as defined under "Definitions," ASME Boiler and Pressure Vessel Code, Section IX. This specification makes no provision for any difference in weld quality requirements regardless of the weld joint type employed (single or double) in making the weld. Where backing rings or strips are employed, the ring or strip material shall be of the same P-Number (Table QW-422 of Section IX) as the plate being joined. Backing rings or strips shall be completely removed after welding, prior to any required radiography, and the exposed weld surface shall be examined visually for conformance to the requirements of 5.2.3 Welds made by procedures employing backing strips or rings which remain in place are prohibited. Welding procedures, and welding operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

5.2.2 Except as provided in 5.2.2.1 and 5.2.2.2, welds shall be made in their entirety by processes involving the deposition of filler metal.

5.2.2.1 For Class 4 pipe employing multiple passes, the root-pass may be without the addition of filler metal.

5.2.2.2 For Class 4 pipe, the weld surface exposed inside the pipe may result from a single pass made from the inside of the pipe without the addition of filler metal.

5.2.2.3 All single-welded pipe shall be completely radiographed.

5.2.3 The weld surface on either side of the weld may be flush with the base plate or may have a reasonably uniform crown, not to exceed $\frac{1}{8}$ in. [3 mm]. Any weld reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement should be reasonably smooth and free from irregularities. The deposited metal shall be fused uniformly into the plate surface. No concavity of contour is permitted unless the resulting thickness of weld metal is equal to or greater than the minimum thickness of the adjacent base metal.

5.2.4 Weld defects shall be repaired by removal to sound metal and rewelding. Subsequent heat treatment and examination (that is, visual, radiographic, and dye penetrant) shall be as required on the original welds.

5.3 *Heat Treatment:*

5.3.1 For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. Unless otherwise stated in the order, heat-treatment shall consist of heating the material to a minimum temperature of 1900°F [1040°C] except for S31254 and S32654 which shall be heated to a minimum temperature of 2100°F [1150°C], S30815 which shall be heated to a minimum temperature of 1920°F [1050°C], and S24565 which shall be heated to a minimum temperature of 2050°F [1120°C], all treatments being followed by quenching in water or rapidly cooling by other means.

5.3.2 The purchase order shall specify one of the following conditions if the heat-treated condition specified in 5.3.1 is not desired by the purchaser:

5.3.2.1 *A final heat-treatment temperature under 1900°F [1040°C]* — Each pipe supplied under this requirement shall be stenciled with the final heat-treatment temperature in degrees Fahrenheit or degrees Celsius after the suffix "HT". Controlled structural or special service characteristics may be specified as a guide for the most suitable heat treatment.

5.3.2.2 *No final heat treatment of pipe fabricated of plate that has been solution heat treated at temperatures required by this specification* — Each pipe supplied under this requirement shall be stenciled with the suffix "HT-O".

5.3.2.3 *No final heat treatment of pipe fabricated of plate that has not been solution heat treated* — Each pipe supplied under this requirement shall be stenciled with the suffix "HT-SO".

5.4 A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in Grades 321, 347, and 348. When specified by the purchaser, a lower temperature stabilization or resolution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S5).

6. Chemical Composition

6.1 The chemical composition of the plate shall conform to the requirements of the applicable specification and grade listed in Specification A 240.

6.2 Unless otherwise specified in the purchase order, the chemical composition of the welding filler metal shall conform to the requirements of the applicable AWS specification for the corresponding grade shown in Table 1, except that for 304N, 304LN, 316N, 316LN,

and S30815, the nitrogen and cerium contents shall be within the range specified for these materials in Specification A 240. The method of analysis for nitrogen and cerium shall be a matter of agreement between the purchaser and manufacturer. Grades with no filler metal classification indicated shall be welded with filler metals producing deposited weld metal having a composition in accordance with the chemical composition specified for the plate. The purchaser may choose a higher-alloy filler metal when needed for corrosion resistance.

7. Permissible Variations in Dimensions

7.1 *Permissible Variations* — The dimensions at any point in a length of pipe shall not exceed the following:

7.1.1 *Outside Diameter* — Based on circumferential measurement, ±0.5% of the specified outside diameter.

7.1.2 *Out-of-Roundness* — Difference between major and minor outside diameters, 1%.

7.1.3 *Alignment* — Using a 10-ft or 3-m straightedge placed so that both ends are in contact with the pipe, $\frac{1}{8}$ in. [3 mm].

7.1.4 *Thickness* — The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. [0.3 mm] under the nominal thickness.

8. Workmanship, Finish, and Appearance

8.1 The finished pipe shall have a workmanlike finish.

8.2 *Repair of Plate Defects by Machining or Grinding* — Pipe showing slivers may be machined or ground inside or outside to a depth which shall ensure the removal of all included scale and slivers, providing the wall thickness is not reduced below the specified minimum wall thickness. Machining or grinding shall follow inspection of the pipe as rolled, and shall be followed by supplementary visual inspection.

8.3 *Repair of Plate Defects by Welding* — Defects which violate minimum wall thickness may be repaired by welding, but only with the approval of the purchaser. Areas shall be suitably prepared for welding with tightly closed defects removed by grinding. Open, clean defects, such as pits or impressions, may require no preparation. All welders, welding operators, and weld procedures shall be qualified to the ASME Boiler and Pressure Vessel Code, Section IX. Unless the purchaser specifies otherwise, pipe required to be heat treated under the provisions of 5.3, shall be heat treated or reheat treated following repair welding. Repaired lengths, where repair depth is greater than $\frac{1}{4}$ of the thickness, shall be pressure tested or repressure tested after repair and heat treatment (if any). Repair welds shall also be examined by suitable nondestructive examination techniques, including any techniques specifically required of the primary weld.

8.4 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

9. Heat Analysis

9.1 An analysis of each heat of steel shall be made by the plate manufacturer to determine the percentages of the elements prescribed in Specification A 240. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall conform to the requirements prescribed in Specification A 240.

10. Product Analysis

10.1 For each lot of 500 ft [150m] of pipe or fraction thereof, analysis shall be made by the manufacturer from the finished pipe of the plate and of the weld deposit. Drillings for analysis may be taken from the mechanical test specimens. The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements of Section 6, subject to the product analysis tolerances of Table 1 in Specification A 480/A 480M.

10.2 If the analysis of one of the tests specified in 10.1 does not conform to the requirements specified in Section 6, analyses shall be made on additional pipe of double the original number from the same lot, each of which shall conform to the requirements specified.

11. Tensile Requirements

11.1 The plate used in making the pipe shall conform to the requirements as to tensile properties of the applicable specifications listed in Table 1 Tension tests made by the plate manufacturer shall qualify the plate material.

11.2 The transverse tension test taken across the welded joint specimen shall have a tensile strength not less than the specified minimum tensile strength of the plate.

12. Transverse Guided-Bend Weld Tests

12.1 Two bend test specimens shall be taken transversely from the pipe. Except as provided in 12.2, one shall be subject to a face guided-bend test and the second to a root guided-bend test. One specimen shall be bent with the inside surface of the pipe against the plunger, and the other with the outside surface against the plunger.

12.2 For wall thicknesses over $\frac{3}{8}$ in. [9.5 mm] but less than $\frac{3}{4}$ in. [19 mm] side-bend tests may be made instead of the face and root-bend tests. For specified wall thicknesses $\frac{3}{4}$ in. [19 mm] and over, both specimens shall be subjected to the side-bend tests. Side-bend specimens shall be bent so that one of the side surfaces becomes the convex surface of the bend specimen.

12.3 The bend test shall be acceptable if no cracks or other defects exceeding $\frac{1}{8}$ in. [3 mm] in any direction be present in the weld metal or between the weld and the pipe metal after bending. Cracks which originate along the edges of the specimen during testing, and that are less than $\frac{1}{4}$ in. [6.5 mm] measured in any direction shall not be considered.

13. Test Specimens and Methods of Testing

13.1 Transverse tension and bend test specimens shall be taken from the end of the finished pipe; the transverse tension and bend test specimens shall be flattened cold before final machining to size.

13.2 As an alternative to the requirements of 13.1, the test specimens may be taken from a test plate of the same material as the pipe, which is attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

13.3 Tension test specimens shall be made in accordance with Section IX, Part QW, Paragraph QW-150 of the *ASME Boiler and Pressure Vessel Code* and shall be one of the types shown in QW-462.1 of that code.

13.3.1 Reduced-section specimens conforming to the requirements given in QW-462.1(b) may be used for tension tests on all thicknesses of pipe having outside diameter greater than 3 in. [76 mm].

13.3.2 Turned specimens conforming to the requirements of QW-462.1(d) may be used for tension tests.

13.3.2.1 If turned specimens are used as given in 13.3.2.2 and 13.3.2.3, one complete set shall be made for each required tension test.

13.3.2.2 For thicknesses to and including $1\frac{1}{4}$ in. [32 mm], a single turned specimen may be used.

13.3.2.3 For thicknesses over $1\frac{1}{4}$ in. [32 mm], multiple specimens shall be cut through the full thickness of the weld with their centers parallel to the material surface and not over 1 in. [25 mm] apart. The centers of the specimens adjacent to material surfaces shall not exceed $\frac{5}{8}$ in. [16 mm] from the surface.

13.4 The test specimens shall not be cut from the pipe or test plate until after final heat treatment.

14. Mechanical Tests Required

14.1 *Transverse Tension Test* — One test shall be made to represent each lot (see Note 2) of finished pipe.

NOTE 2 — The term "lot" applies to all pipe of the same grade (may include more than one heat of steel) within a $\frac{3}{16}$ in. [4.7 mm] range of thickness and welded to the same weld procedure, and when heat treated, done so to the same heat-treating procedure and in the same furnace. The maximum lot size shall be 200 linear ft [60 m] of pipe.

14.2 *Transverse Guided-Bend Weld Test* — One test (two specimens) shall be made to represent each lot (Note 2) of finished pipe.

14.3 *Hydrostatic Test* — Each length of pipe shall be subjected to a hydrostatic test in accordance with Specification A 530/A 530M, unless specifically exempted under the provision of 12.4 Pressure shall be held for a sufficient time to permit the inspector to examine the entire length of the welded seam.

14.4 The purchaser, with the agreement of the manufacturer, may complete the hydrostatic test requirement with the system pressure test, which may be lower or higher than the specification test pressure, but in no case shall the test pressure be lower than the system design pressure. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory marking the letters "NH".

15. Radiographic Examination

15.1 For Classes 1, 3, and 4 pipe, all welded joints shall be completely examined by radiography.

15.2 For Class 5 pipe, the welded joints shall be spot radiographed to the extent of not less than 12 in. [300 mm] of radiograph per 50 ft [15 m] of weld.

15.3 For Classes 1, 3, and 4 pipe, radiographic examination shall be in accordance with the requirements of the *ASME Boiler and Pressure Vessel Code*, Section VIII, latest edition, Paragraph UW-51

15.4 For Class 5 pipe, radiographic examination shall be in accordance with the requirements of the *ASME Boiler and Pressure Vessel Code*, Section VIII, Division 1, latest edition, Paragraph UW-52

15.5 Radiographic examination may be performed prior to heat treatment.

16. Lengths

16.1 Circumferentially welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

17. Product Marking

17.1 In addition to the marking prescribed in Specification A 530/A 530M, the markings on each length of pipe shall include the plate material designations as shown in Table 1, the marking requirements of 5.3 and 14.4, and Class 1, 2, 3, or 4, as appropriate (see 1.3).

17.2 *Bar Coding*—In addition to the requirements in 17.1 bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

18. Keywords

18.1 arc welded steel pipe; austenitic stainless steel; chromium-nickel steel; fusion welded steel pipe; high temperature application; steel pipe; temperature service applications, high; welded steel pipe

TABLE 1
PLATE AND FILLER METAL SPECIFICATIONS

Grade	UNS Designation	Material, Type	ASTM Plate Specification No. and Grade	Filler Metal Classification and UNS Designation [Note (1)] for Applicable [Note (2)] AWS Specification											
				A5.4		A5.9		A5.11		A5.14		A5.22		A5.30	
				Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS
304	S30400	304	A 240 Type 304	E308	W30810	ER308	S30880 W30840	. . .	. . .	. . .	. . .	E308T	W30831	IN308	S30880
304L	S30403	304L	A 240 Type 304	E308L	W30813	ER308L	S30883 W30843	. . .	. . .	. . .	. . .	E308LT	W30835	IN308L	S30883
304N	S30451	304N	A 240 Type 304N	E308	W30810	ER308	S30880 W30840	. . .	. . .	. . .	. . .	E308T	W30831	IN308	S30880
304LN	S30453	304LN	A 240 Type 304LN	E308L	W30813	ER308L	S30883 W30843	. . .	. . .	. . .	. . .	W308LT	W30835	IN308L	S30883
304H	S30409	304H	A 240 Type 304H	E308H	W30810	ER308	S30880 W30840	. . .	. . .	. . .	. . .	E308T	W30831	IN308	S30880
309Cb	S30940	309Cb	A 240, Type 309Cb	E309Cb	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
309S	S30908	309S	A 240, Type 309S	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
310Cb	S31040	310Cb	A 240, Type 310Cb	E310Cb	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
310S	S31008	310S	A 240, Type 310S	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
316	S31600	316	A 240 Type 316	E316	W31610	ER316	S31680 W31640	. . .	. . .	. . .	. . .	E316T	W31631	IN316	S31680
316L	S31603	316L	A 240 Type 316L	E316L	W31613	ER316L	S31683 W31643	. . .	. . .	. . .	. . .	E316LT	W31635	IN316L	S31683
316N	S31651	316N	A 240 Type 316N	E316	W31610	ER316	S31680 W31640	. . .	. . .	. . .	. . .	E316T	W31631	IN316	S31680
316LN	S31653	316LN	A 240 Type 316LN	E316L	W31613	ER316L	S31683 W31643	. . .	. . .	. . .	. . .	E316LT	W31635	IN316L	S31683
316H	S31609	316H	A 240 Type 316H	E316H	W31610	ER316H	S31680 W31640	. . .	. . .	. . .	. . .	E316T	W31631	IN316	S31680
321	S32100	321	A 240 Type 321	E347	W34710	ER321 ER347	S32180 W32140 S34780 W34740	. . .	. . .	. . .	. . .	E347T	W34733	IN348	S34780
347	S34700	347	A 240 Type 347	E347	W34710	ER347	S34780 W34740	. . .	. . .	. . .	. . .	E347T	W34733	IN348	S34780
348	S34800	348	A 240 Type 348	E347	W34710	ER347	S34780 W34740	. . .	. . .	. . .	. . .	E347T	W34733	IN348	S34780
XM-19	S22100	XM-19	A 240 Type XM-19	E209	W32210	ER209	S20980 W32240	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
XM-29	S28300	XM-29	A 240 Type XM-29	E240	W32410	ER240	S23980 W32440	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S31254	. . .	A 240 S31254	. . .	. . .	. . .	. . .	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	. . .	. . .	. . .	. . .
. . .	S30815	. . .	A 240 S30815	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S31725	. . .	A 240 S31725	. . .	. . .	. . .	. . .	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	. . .	. . .	. . .	. . .
. . .	S31726	. . .	A 240 S31726	. . .	. . .	. . .	. . .	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	. . .	. . .	. . .	. . .
. . .	S30600 [Note (3)]	. . .	A 240 S30600 [Note (3)]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S24565	. . .	A 240 S24565	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S30415	. . .	A 240 S30415	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S32654	. . .	A 240 S32654	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	N08367	. . .	A 240 N08367	. . .	. . .	. . .	. . .	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	. . .	. . .	. . .	. . .

NOTES:
(1) New designation established in accordance with ASTM E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).
(2) Choice of American Welding Society specification depends on the welding process used.
(3) In previous editions, S30600 was incorrectly shown as S01815.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Tension and Bend Tests

S2.1 Tension tests (Section 11) and bend tests (Section 12) shall be made on specimens to represent each length of pipe. Failure of any test specimen to meet the requirements shall be cause for the rejection of the pipe length represented.

S3. Penetrant Oil and Powder Examination

S3.1 All welded joints shall be subjected to examination by a penetrant oil and powder method. The details of the method and the disposition of flaws detected shall be a matter for agreement between the purchaser and the manufacturer.

S4. Ferrite Control in Weld Deposits

S4.1 The ferrite content of the deposited weld metal in any length of pipe may be determined. The procedural details pertaining to this subject (that is, welding; plate and weld deposit chemistry; testing equipment and method; number and location of test sites; and ferrite control limits) shall be a matter for agreement between the purchaser and the manufacturer.

S5. Stabilizing Heat Treatment

S5.1 Subsequent to the heat treatment required in 5.3, Grades 321, 347, and 348 shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S6. Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE 3 — Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S5 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium.

SPECIFICATION FOR CARBON AND FERRITIC ALLOY STEEL FORGED AND BORED PIPE FOR HIGH-TEMPERATURE SERVICE

SA-369/SA-369M

(Identical with ASTM Specification A 369/A 369M-92.)

1. Scope

1.1 This specification covers heavy-wall carbon and alloy steel pipe (Note 1) made from turned and bored forgings and is intended for high-temperature service. Pipe ordered under this specification shall be suitable for bending and other forming operations and for fusion welding. Selection will depend on design, service conditions, mechanical properties and high-temperature characteristics.

NOTE 1—The use of the word "pipe" throughout the several sections of this specification is used in the broad sense and intended to mean pipe headers, or leads.

NOTE 2—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.2 Several grades of ferritic steels are covered. Their compositions are given in Table 1.

1.3 Supplementary requirements (S1 to S6) of an optional nature are provided. These supplementary requirements call for additional tests to be made, and when desired shall be so stated in the order, together with the number of such tests required.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 290 Method for Semi-Guided Bend Test for Ductility of Metallic Materials

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

2.2 *ASME Boiler and Pressure Vessel Code:* Section Section IX Welding Qualifications

2.3 *ANSI Standard:*

B46.1 Surface Texture

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material to this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, centimeters, or number of lengths),

4.1.2 Name of material (forged and bored pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (inside diameter and minimum wall thickness),

4.1.5 Length (Permissible Variations in Length Section of Specification A 530/A 530M),

4.1.6 End finish (Section 12),

4.1.7 Optional requirements (Sections 8, Supplementary Requirements S1 to S6; 13.2),

4.1.8 Test report required (Certification Section of Specification A 530/A 530M),

4.1.9 Specification designation, and

4.1.10 Special requirements or exceptions to this specification.

5. Materials and Manufacture

5.1 *Discard:*

5.1.1 A sufficient discard shall be made from each ingot to secure freedom from injurious defects. The steel shall have a homogeneous structure.

5.2 *Manufacture:*

5.2.1 Material for forging shall consist of ingots or of blooms, billets, or solid-rolled bars forged or rolled from an ingot, and cut to the required length by a process that will not produce injurious defects in the forging.

5.2.2 The material shall be forged (Note 3) by hammering or pressing, and shall be brought as nearly as practicable to the finished shape and size by hot working.

NOTE 3—The cross-sectional area of the solid forging shall have a reduction by forging or by rolling and forging from that of the ingot in the ratio of not less than 3 to 1.

5.2.3 Unless otherwise specified, the final forging operation shall be followed by a treatment suitable to the grade as specified in 5.4.

5.3 *Machining:*

5.3.1 All forgings shall have both the inner and outer surfaces machined.

5.3.2 After heat treatment, the pipe shall be machined to a finish with a roughness value no greater than 250-μin. [6.4-μm] arithmetical average deviation (AA), terms as defined in ANSI B46.1-1962, unless otherwise specified.

5.4 *Heat Treatment:*

5.4.1 All pipe of the grades shown in Table 1 other than FPA, FPB, FP1, FP2, FP12, and FP91 shall be reheated and furnished in the full-annealed or normalized and tempered condition. If furnished in the normalized and tempered condition (Note 4), the temperature for tempering shall be 1250°F [680°C] or higher for Grades FP5, FP7, FP9, FP21, and FP22, and 1200°F [650°C] or higher for Grades FP36 and FP11.

NOTE 4—It is recommended that the temperature for tempering should be at least 100°F [50°C] above the intended service temperature; consequently, the purchaser should advise the manufacturer if the service temperature is to be over 1100°F [600°C].

5.4.2 Pipe in Grades FPA and FPB as a final heat treatment shall be either normalized or shall be given a stress relieving treatment at 1200 to 1300°F [650 to 705°C]. Pipe in Grades FP1, FP2, and FP12, as a final heat treatment shall be given a stress-relieving treatment at 1200 to 1300°F [650 to 705°C].

NOTE 5—Certain of the ferritic steels covered by this specification tend to harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperature. Therefore, operations involving heating such steels above their critical temperatures, such as welding, hot-bending and other forming operations, should be followed by suitable heat treatment.

5.4.3 Except when Supplementary S6 is specified by the purchaser, Grade FP91 shall be normalized and tempered by reheating within the temperature range of 1900 to 2000°F [1040 to 1095°C], followed by air cooling and tempering at a sub-critical temperature of 1350°F [730°C] minimum.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall conform to the requirements specified.

7.2 In the case of large ingots poured from two or more heats, the weighted average of the chemical determinations of the several heats, made in accordance with 7.1, shall conform to the requirements specified in Section 6.

8. Product Analysis

8.1 At the request of the purchaser, a product analysis shall be made by the manufacturer on every heat.

8.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 6.

8.3 If the analysis of one of the tests specified in Sections 7 or 8 does not conform to the requirements specified in Section 6 an analysis of each billet or pipe from the same heat may be made, and all billets or pipes conforming to the requirements shall be accepted.

9. Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2. Tests for acceptance shall be made after final heat treatment of the forging.

10. Mechanical Tests Required

10.1 *Transverse or Longitudinal Tension Test*—One test shall be made on a specimen from one end of one length of pipe representing each heat in each heat-treatment lot.

10.2 *Flattening Test*—For pipe NPS 14 or less, and diameter to wall thickness ratios of more than 7.0, a flattening test shall be carried out in accordance with Specification A 530/A 530M. A test shall be carried out on a specimen taken from one end of each length of pipe.

10.3 *Bend Test*—For pipe NPS 14 or NPS where diameters to wall thickness ratio is 7.0 or less, a bend test shall be carried out in accordance with Test Method E 290. Unless otherwise specified, the test specimens shall be taken in a transverse direction. The diameter of the pin shall be $\frac{2}{3}t$ for longitudinal specimens or $1\frac{1}{3}t$ for transverse specimens, where t is the specimen thickness. The bend test specimens shall be bent at room temperature through 180° without cracking. One bend test shall be taken from one end of each length of pipe.

11. Workmanship

11.1 The pipe shall conform to the sizes and shapes specified by the purchaser.

12. Ends

12.1 Pipe ends shall be machined as specified in the purchase order.

13. Finish

13.1 The finished pipe shall be reasonably straight and shall have a workmanlike finish.

13.2 Repair of defects by welding shall be permitted only subject to the approval of the purchaser. Defects shall be thoroughly chipped or ground out before welding. Only qualified operators and procedures in accordance with the ASME Boiler and Pressure Vessel Code, Section IX, shall be used. Local or full heat treatment in accordance with 5.4 shall follow welding. Local grinding following welding and retreating shall be considered as meeting the requirements of 5.3.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include the wall thickness, piece mark, length, and additional symbol “S” if the pipe conforms to the supplementary requirements specified in Supplementary Requirements S1 to S5, and the heat number or the manufacturer’s number by which the heat can be identified. Indentation stamping, instead of stenciling, will be permitted only with the written approval of the purchaser.

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %			
Grade	FPA	FPB	FP1	FP2
Carbon	0.25 max	0.30 max	0.10–0.20	0.10–0.20
Manganese	0.27–0.93	0.29–1.06	0.30–0.80	0.30–0.61
Phosphorus, max	0.035	0.035	0.025	0.025
Sulfur, max	0.035	0.035	0.025	0.025
Silicon	0.10 min	0.10 min	0.10–0.50	0.10–0.30
Chromium	. . .	. . .	. . .	0.50–0.81
Molybdenum	. . .	. . .	0.44–0.65	0.44–0.65
Grade	**FP5**	**FP9**	**FP11**	**FP12**
Carbon	0.15 max	0.15 max	0.05–0.15	0.05–0.15
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.61
Phosphorus, max	0.025	0.030	0.025	0.025
Sulfur, max	0.025	0.030	0.025	0.025
Silicon	0.50 max	0.50–1.00	0.50–1.00	0.50 max
Chromium	4.00–6.00	8.00–10.00	1.00–1.50	0.80–1.25
Molybdenum	0.45–0.65	0.90–1.10	0.44–0.65	0.44–0.65
Grade	**FP21**	**FP22**	**FP91**	
Carbon	0.05–0.15	0.05–0.15	0.08–0.12	
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	
Phosphorus, max	0.025	0.025	0.025	
Sulfur, max	0.025	0.025	0.025	
Silicon	0.50 max	0.50 max	0.20–0.50	
Chromium	2.65–3.35	1.90–2.60	8.00–9.50	
Molybdenum	0.80–1.06	0.87–1.13	0.85–1.05	
			Others:	
			Ni 0.40 max	
			V 0.18–0.25	
			Cb 0.06–0.10	
			N 0.03–0.07	
			Al 0.04 max	

TABLE 2
TENSILE REQUIREMENTS

Grade	FPA	FPB	FP1, FP2	FP12	FP91	All Others
Tensile strength, min; ksi [MPa]	48 [330]	60 [415]	55 [380]	60 [415]	85 [585]	60 [415]
Yield strength, min; ksi [MPa]	30 [210]	35 [240]	30 [210]	32 [220]	60 [415]	30 [210]

	Elongation Requirements							
	FPA		FPB		FP91		All Others	
Grade	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. or 50 mm, min, %:								
Basic minimum elongation for wall $^{5}/_{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full-section	35	25	30	17	27	18	30	20
When standard round 2-in. or 50-mm gage length test specimen is used	28	20	22	12	20	13	22	14

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Additional Tension Test

S1.1 An additional tension test shall be made on a specimen from one or each end of each pipe. If this supplementary requirement is specified, the number of tests per pipe required shall be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest.

S2. Additional Flattening or Bend Tests

S2.1 The appropriate flattening or bend test may be made on specimens from both ends of each length of pipe. Crop ends may be used. If the specimen from either end of any length fails to conform to the specific requirement, that length shall be rejected.

S3. Ultrasonic Tests

S3.1 Each pipe shall be ultrasonically tested to determine its soundness throughout the entire length of the pipe. Until suitable standards are established, the basis for rejection of material shall be a matter of agreement between the manufacturer and purchaser.

S4. Hydrostatic Test

S4.1 A hydrostatic pressure test shall be applied as agreed upon by the manufacturer and purchaser.

S5. Metal Structure and Etching Tests

S5.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S6. Alternative Heat Treatment—Grade FP91

S6.1 Grade FP91 shall be normalized in accordance with 5.5.3 and tempered at a temperature, to be specified by the purchaser, less than 1350°F [730°C]. It shall be the purchaser's responsibility to subsequently temper at 1350°F [730°C] minimum. All mechanical tests shall be made on material heat treated in accordance with 5.4.3. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S6" shall be included with the required marking of the pipe.

STANDARD TEST METHODS AND DEFINITIONS FOR MECHANICAL TESTING OF STEEL PRODUCTS

SA-370

(Identical with ASTM Specification A 370-96) 98

1. Scope

1.1 These test methods cover procedures and definitions for the mechanical testing of wrought and cast steel products. The various mechanical tests herein described are used to determine properties required in the product specifications. Variations in testing methods are to be avoided and standard methods of testing are to be followed to obtain reproducible and comparable results. In those cases where the testing requirements for certain products are unique or at variance with these general procedures, the product specification testing requirements shall control.

1.2 The following mechanical tests are described:

	Sections
Tension	5 to 13
Bend	14
Hardness	15
Brinell	16
Rockwell	17
Portable	18
Impact	19 to 28
Keywords	29

1.3 Annexes covering details peculiar to certain products are appended to these test methods as follows:

	Annex
Bar Products	1
Tubular Products	2
Fasteners	3
Round Wire Products	4
Significance of Notched-Bar Impact Testing	5
Converting Percentage Elongation of Round Specimens to Equivalents for Flat Specimens	6
Testing Multi-Wire Strand	7
Rounding of Test Data	8
Methods for Testing Steel Reinforcing Bars	9
Procedure for Use and Control of Heat-Cycle Simulation	10

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 When this document is referenced in a metric product specification, the yield and tensile values may be determined in inch-pound (ksi) units then converted into SI (MPa) units. The elongation determined in inch-pound gage lengths of 2 or 8 in. may be reported in SI unit gage lengths of 50 or 200 mm, respectively, as applicable. Conversely, when this document is referenced in an inch-pound product specification, the yield and tensile values may be determined in SI units then converted into inch-pound units. The elongation determined in SI unit gage lengths of 50 or 200 mm may be reported in inch-pound gage lengths of 2 or 8 in., respectively, as applicable.

1.6 Attention is directed to Practice A 880 when there may be a need for information on criteria for evaluation of testing laboratories.

1.7 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use

A 833 Practice for Indentation Hardness of Metallic Materials by Comparison Hardness Testers

A 880 Practice for Criteria for Use in Evaluation of Testing Laboratories and Organizations for Examination and Inspection of Steel, Stainless Steel, and Related Alloys

E 4 Practices for Force Verification of Testing Machines

E 6 Terminology Relating to Methods of Mechanical Testing

E 8 Test Methods for Tension Testing of Metallic Materials

E 8M Test Methods for Tension Testing of Metallic Materials [Metric]

E 10 Test Method for Brinell Hardness of Metallic Materials

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 83 Practice for Verification and Classification of Extensometers

E 110 Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers

E 190 Method for Guided Bend Test for Ductility of Welds

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

E 290 Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials

E 1595 Practice for Evaluating the Performance of Mechanical Testing Laboratories

2.2 *Other Document:*

ASME Boiler and Pressure Vessel Code, Section VIII, Division I, Part UG-84

3. General Precautions

3.1 Certain methods of fabrication such as bending, forming, and welding, or operations involving heating, may affect the properties of the material under test. Therefore, the product specifications cover the stage of manufacture at which mechanical testing is to be performed. The properties shown by testing prior to fabrication may not necessarily be representative of the product after it has been completely fabricated.

3.2 Improper machining or preparation of test specimens may give erroneous results. Care should be exercised to assure good workmanship in machining. Improperly machined specimens should be discarded and other specimens substituted.

3.3 Flaws in the specimen may also affect results. If any test specimen develops flaws, the retest provision of the applicable product specification shall govern.

3.4 If any test specimen fails because of mechanical reasons such as failure of testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

4. Orientation of Test Specimens

4.1 The terms "longitudinal test" and "transverse test" are used only in material specifications for wrought products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:

4.1.1 *Longitudinal Test,* unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is parallel to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a longitudinal tension test specimen is in the direction of the greatest extension, and the axis of the fold of a longitudinal bend test specimen is at right angles to the direction of greatest extension (Figs. 1, 2(a), and 2(b)).

4.1.2 *Transverse Test,* unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is at right angles to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a transverse tension test specimen is at right angles to the greatest extension, and the axis of the fold of a transverse bend test specimen is parallel to the greatest extension (Fig. 1).

4.2 The terms "radial test" and "tangential test" are used in material specifications for some wrought circular products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:

4.2.1 *Radial Test,* unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to the axis of the product and coincident

with one of the radii of a circle drawn with a point on the axis of the product as a center (Fig. 2(a)).

4.2.2 *Tangential Test,* unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to a plane containing the axis of the product and tangent to a circle drawn with a point on the axis of the product as a center (Figs. 2(a), 2(b), 2(c), and 2(d)).

TENSION TEST

5. Description

5.1 The tension test related to the mechanical testing of steel products subjects a machined or full-section specimen of the material under examination to a measured load sufficient to cause rupture. The resulting properties sought are defined in Terminology E 6.

5.2 In general the testing equipment and methods are given in Test Methods E 8. However, there are certain exceptions to Test Methods E 8 practices in the testing of steel, and these are covered in these test methods.

6. Test Specimen Parameters

6.1 *Selection* — Test coupons shall be selected in accordance with the applicable product specifications.

6.1.1 *Wrought Steels* — Wrought steel products are usually tested in the longitudinal direction, but in some cases, where size permits and the service justifies it, testing is in the transverse, radial, or tangential directions (see Figs. 1 and 2).

6.1.2 *Forged Steels* — For open die forgings, the metal for tension testing is usually provided by allowing extensions or prolongations on one or both ends of the forgings, either on all or a representative number as provided by the applicable product specifications. Test specimens are normally taken at mid-radius. Certain product specifications permit the use of a representative bar or the destruction of a production part for test purposes. For ring or disk-like forgings test metal is provided by increasing the diameter, thickness, or length of the forging. Upset disk or ring forgings, which are worked or extended by forging in a direction perpendicular to the axis of the forging, usually have their principal extension along concentric circles and for such forgings tangential tension specimens are obtained from extra metal on the periphery or end of the forging. For some forgings, such as rotors, radial tension tests are required. In such cases the specimens are cut or trepanned from specified locations.

6.1.3 *Cast Steels* — Test coupons for castings from which tension test specimens are prepared shall be in accordance with the requirements of Specifications A 703/A 703M or A 781/A 781M, as applicable.

6.2 *Size and Tolerances* — Test specimens shall be the full thickness or section of material as-rolled, or may be machined to the form and dimensions shown in Figs. 3 and 6, inclusive. The selection of size and type of specimen is prescribed by the applicable product specification. Full section specimens shall be tested in 8 in. (200 mm) gage length unless otherwise specified in the product specification.

6.3 *Procurement of Test Specimens* — Specimens shall be sheared, blanked, sawed, trepanned, or oxygen-cut from portions of the material. They are usually machined so as to have a reduced cross section at mid-length in order to obtain uniform distribution of the stress over the cross section and to localize the zone of fracture. When test coupons are sheared, blanked, sawed, or oxygen-cut, care shall be taken to remove by machining all distorted, cold-worked, or heat-affected areas from the edges of the section used in evaluating the test.

6.4 *Aging of Test Specimens* — Unless otherwise specified, it shall be permissible to age tension test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water, heating in oil or in an oven.

6.5 *Measurement of Dimensions of Test Specimens:*

6.5.1 *Standard Rectangular Tension Test Specimens* — These forms of specimens are shown in Fig. 3. To determine the cross-sectional area, the center width dimension shall be measured to the nearest 0.005 in. (0.13 mm) for the 8 in. (200 mm) gage length specimen and 0.001 in. (0.025 mm) for the 2 in. (50 mm) gage length specimen in Fig. 3. The center thickness dimension shall be measured to the nearest 0.001 in. for both specimens.

6.5.2 *Standard Round Tension Test Specimens* — These forms of specimens are shown in Figs. 4 and 5. To determine the cross-sectional area, the diameter shall be measured at the center of the gage length to the nearest 0.001 in. (0.025 mm). (See Table 1.)

6.6 *General* — Test specimens shall be either substantially full size or machined, as prescribed in the product specifications for the material being tested.

6.6.1 Improperly prepared test specimens often cause unsatisfactory test results. It is important, therefore, that care be exercised in the preparation of specimens, particularly in the machining, to assure good workmanship.

6.6.2 It is desirable to have the cross-sectional area of the specimen smallest at the center of the gage length to ensure fracture within the gage length. This is provided for by the taper in the gage length permitted for each of the specimens described in the following sections.

6.6.3 For brittle materials it is desirable to have fillets of large radius at the ends of the gage length.

7. Plate-Type Specimen

7.1 The standard plate-type test specimen is shown in Fig. 3. This specimen is used for testing metallic materials in the form of plate, structural and bar-size shapes, and flat material having a nominal thickness of $^{3}/_{16}$ in. (5 mm) or over. When product specifications so permit, other types of specimens may be used.

NOTE 1 — When called for in the product specification, the 8 in. gage length specimen of Fig. 3 may be used for sheet and strip material.

8. Sheet-Type Specimen

8.1 The standard sheet-type test specimen is shown in Fig. 3. This specimen is used for testing metallic materials in the form of sheet, plate, flat wire, strip, band, and hoop ranging in nominal thickness from 0.005 to $^{3}/_{4}$ in. (0.13 to 19 mm). When product specifications so permit, other types of specimens may be used, as provided in Section 7 (see Note 1).

9. Round Specimens

9.1 The standard 0.500 in. (12.5 mm) diameter round test specimen shown in Fig. 4 is used quite generally for testing metallic materials, both cast and wrought.

9.2 Figure 4 also shows small size specimens proportional to the standard specimen. These may be used when it is necessary to test material from which the standard specimen or specimens shown in Fig. 3 cannot be prepared. Other sizes of small round specimens may be used. In any such small size specimen it is important that the gage length for measurement of elongation be four times the diameter of the specimen (see Note 4, Fig. 4).

9.3 The shape of the ends of the specimens outside of the gage length shall be suitable to the material and of a shape to fit the holders or grips of the testing machine so that the loads are applied axially. Figure 5 shows specimens with various types of ends that have given satisfactory results.

10. Gage Marks

10.1 The specimens shown in Figs. 3 through 6 shall be gage marked with a center punch, scribe marks, multiple device, or drawn with ink. The purpose of these gage marks is to determine the percent elongation. Punch marks shall be light, sharp, and accurately spaced. The localization of stress at the marks makes a hard specimen susceptible to starting fracture at the punch marks. The gage marks for measuring elongation after fracture shall be made on the flat or on the edge of the flat tension test specimen and within the parallel section; for the 8 in. gage length specimen, Fig. 3, one or more sets of 8 in. gage marks may be used, intermediate marks within the gage length being optional. Rectangular 2 in. gage length specimens, Fig. 3, and round specimens, Fig. 4, are gage marked with a double-pointed center punch or scribe marks. One or more sets of gage marks may be used, however, one set must be approximately centered in the reduced section. These same precautions shall be observed when the test specimen is full section.

11. Testing Apparatus and Operations

11.1 *Loading Systems* — There are two general types of loading systems, mechanical (screw power) and hydraulic. These differ chiefly in the variability of the rate of load application. The older screw power machines are limited to a small number of fixed free running crosshead speeds. Some modern screw power machines, and all hydraulic machines permit stepless variation throughout the range of speeds.

11.2 The tension testing machine shall be maintained in good operating condition, used only in the proper loading range, and calibrated periodically in accordance with the latest revision of Practices E 4.

NOTE 2 — Many machines are equipped with stress-strain recorders for autographic plotting of stress-strain curves. It should be noted that some recorders have a load measuring component entirely

separate from the load indicator of the testing machine. Such recorders are calibrated separately.

11.3 *Loading* — It is the function of the gripping or holding device of the testing machine to transmit the load from the heads of the machine to the specimen under test. The essential requirement is that the load shall be transmitted axially. This implies that the centers of the action of the grips shall be in alignment, insofar as practicable, with the axis of the specimen at the beginning and during the test, and that bending or twisting be held to a minimum. For specimens with a reduced section, gripping of the specimen shall be restricted to the grip section. In the case of certain sections tested in full size, nonaxial loading is unavoidable and in such cases shall be permissible.

11.4 *Speed of Testing* — The speed of testing shall not be greater than that at which load and strain readings can be made accurately. In production testing, speed of testing is commonly expressed *(1)* in terms of free running crosshead speed (rate of movement of the crosshead of the testing machine when not under load), or *(2)* in terms of rate of separation of the two heads of the testing machine under load, or *(3)* in terms of rate of stressing the specimen, or *(4)* in terms of rate of straining the specimen. The following limitations on the speed of testing are recommended as adequate for most steel products:

NOTE 3 — Tension tests using closed-loop machines (with feedback control of rate) should not be performed using load control, as this mode of testing will result in acceleration of the crosshead upon yielding and elevation of the measured yield strength.

11.4.1 Any convenient speed of testing may be used up to one half the specified yield point or yield strength. When this point is reached, the free-running rate of separation of the crossheads shall be adjusted so as not to exceed $\frac{1}{16}$ in. per min per inch of reduced section, or the distance between the grips for test specimens not having reduced sections. This speed shall be maintained through the yield point or yield strength. In determining the tensile strength, the free-running rate of separation of the heads shall not exceed $\frac{1}{2}$ in. per min per inch of reduced section, or the distance between the grips for test specimens not having reduced sections. In any event, the minimum speed of testing shall not be less than $\frac{1}{10}$ the specified maximum rates for determining yield point or yield strength and tensile strength.

11.4.2 It shall be permissible to set the speed of the testing machine by adjusting the free running crosshead speed to the above specified values, inasmuch as the rate of separation of heads under load at these machine settings is less than the specified values of free running crosshead speed.

11.4.3 As an alternative, if the machine is equipped with a device to indicate the rate of loading, the speed of the machine from half the specified yield point or yield strength through the yield point or yield strength may be adjusted so that the rate of stressing does not exceed 100,000 psi (690 MPa)/min. However, the minimum rate of stressing shall not be less than 10,000 psi (70 MPa)/min.

12. Terminology

12.1 For definitions of terms pertaining to tension testing, including tensile strength, yield point, yield strength, elongation, and reduction of area, reference should be made to Terminology E 6.

13. Determination of Tensile Properties

13.1 *Yield Point* — Yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. Yield point is intended for application only for materials that may exhibit the unique characteristic of showing an increase in strain without an increase in stress. The stress-strain diagram is characterized by a sharp knee or discontinuity. Determine yield point by one of the following methods:

13.1.1 *Drop of the Beam or Halt of the Pointer Method* — In this method apply an increasing load to the specimen at a uniform rate. When a lever and poise machine is used, keep the beam in balance by running out the poise at approximately a steady rate. When the yield point of the material is reached, the increase of the load will stop, but run the poise a trifle beyond the balance position, and the beam of the machine will drop for a brief but appreciable interval of time. When a machine equipped with a load-indicating dial is used there is a halt or hesitation of the load-indicating pointer corresponding to the drop of the beam. Note the load at the “drop of the beam” or the “halt of the pointer” and record the corresponding stress as the yield point.

13.1.2 *Autographic Diagram Method* — When a sharp-kneed stress-strain diagram is obtained by an autographic recording device, take the stress corresponding to the top of the knee (Fig. 7), or the stress at which the curve drops as the yield point.

13.1.3 *Total Extension Under Load Method* — When testing material for yield point and the test specimens may not exhibit a well-defined disproportionate deformation that characterizes a yield point as measured by the drop of the beam, halt of the pointer, or autographic diagram methods described in 13.1.1 and 13.1.2, a value equivalent to the yield point in its practical significance may be determined by the following method and may be recorded as yield point: Attach a Class C or better extensometer (Notes 4 and 5) to the specimen. When the load producing a specified extension (Note 6) is reached record the stress corresponding to the load as the yield point, and remove the extensometer (Fig. 8).

NOTE 4 — Automatic devices are available that determine the load at the specified total extension without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated. Multiplying calipers and other such devices are acceptable for use provided their accuracy has been demonstrated as equivalent to a Class C extensometer.

NOTE 5 — Reference should be made to Practice E 83.

NOTE 6 — For steel with a yield point specified not over 80 000 psi (550 MPa), an appropriate value is 0.005 in./in. of gage length. For values above 80 000 psi, this method is not valid unless the limiting total extension is increased.

NOTE 7 — The shape of the initial portion of an autographically determined stress-strain (or a load-elongation) curve may be influenced by numerous factors such as the seating of the specimen in the grips, the straightening of a specimen bent due to residual stresses, and the rapid loading permitted in 11.4.1. Generally, the abberations in this portion of the curve should be ignored when fitting a modulus line, such as that used to determine the offset or extension-under-load yield, to the curve.

13.2 *Yield Strength* — Yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. The deviation is expressed in terms of strain, percent offset, total extension under load, etc. Determine yield strength by one of the following methods:

13.2.1 *Offset Method* — To determine the yield strength by the "offset method," it is necessary to secure data (autographic or numerical) from which a stress-strain diagram may be drawn. Then on the stress-strain diagram (Fig. 9) lay off *Om* equal to the specified value of the offset, draw *mn* parallel to *OA*, and thus locate *r*, the intersection of *mn* with the stress-strain curve corresponding to load *R* which is the yield strength load. In recording values of yield strength obtained by this method, the specified value of "offset" used shall be stated in parentheses after the term yield strength, thus:

Yield strength (0.2% offset) = 52 000 psi (360 MPa)

In using this method, a minimum extensometer magnification of 250 to 1 is required. A Class B1 extensometer meets this requirement (see Notes 5 and 7). See also Note 8 for automatic devices.

13.2.2 *Extension Under Load Method* — For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams were plotted, the total strain corresponding to the stress at which the specified offset (see Notes 8 and 9) occurs will be known within satisfactory limits. The stress on the specimen, when this total strain is reached, is the value of the yield strength. The total strain can be obtained satisfactorily by use of a Class B1 extensometer (Notes 4, 5, and 7).

NOTE 8 — Automatic devices are available that determine offset yield strength without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated.

NOTE 9 — The appropriate magnitude of the extension under load will obviously vary with the strength range of the particular steel under test. In general, the value of extension under load applicable to steel at any strength level may be determined from the sum of the proportional strain and the plastic strain expected at the specified yield strength. The following equation is used:

$$\text{Extension under load, in./in. of gage length} = (YS/E) + r$$

where:

YS = specified yield strength, psi or MPa,
E = modulus of elasticity, psi or MPa, and
r = limiting plastic strain, in/in.

13.3 *Tensile Strength* — Calculate the tensile strength by dividing the maximum load the specimen sustains during a tension test by the original cross-sectional area of the specimen.

13.4 *Elongation:*

13.4.1 Fit the ends of the fractured specimen together carefully and measure the distance between the gage marks to the nearest 0.01 in. (0.25 mm) for gage lengths of 2 in. and under, and to the nearest 0.5% of the gage length for gage lengths over 2 in. A percentage scale reading to 0.5% of the gage length may be used. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In recording elongation values,

give both the percentage increase and the original gage length.

13.4.2 If any part of the fracture takes place outside of the middle half of the gage length or in a punched or scribed mark within the reduced section, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements specified, no further testing is indicated, but if the elongation is less than the minimum requirements, discard the test and retest.

13.5 *Reduction of Area* — Fit the ends of the fractured specimen together and measure the mean diameter or the width and thickness at the smallest cross section to the same accuracy as the original dimensions. The difference between the area thus found and the area of the original cross section expressed as a percentage of the original area, is the reduction of area.

BEND TEST

14. Description

14.1 The bend test is one method for evaluating ductility, but it cannot be considered as a quantitative means of predicting service performance in bending operations. The severity of the bend test is primarily a function of the angle of bend and inside diameter to which the specimen is bent, and of the cross section of the specimen. These conditions are varied according to location and orientation of the test specimen and the chemical composition, tensile properties, hardness, type, and quality of the steel specified. Method E 190 and Test Method E 290 may be consulted for methods of performing the test.

14.2 Unless otherwise specified, it shall be permissible to age bend test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water, heating in oil, or in an oven.

14.3 Bend the test specimen at room temperature to an inside diameter, as designated by the applicable product specifications, to the extent specified without major cracking on the outside of the bent portion. The speed of bending is ordinarily not an important factor.

HARDNESS TEST

15. General

15.1 A hardness test is a means of determining resistance to penetration and is occasionally employed to obtain a quick approximation of tensile strength. Tables 2A, 2B, 2C, and 2D are for the conversion of hardness measurements from one scale to another or to approximate tensile strength. These conversion values have been obtained from computer-generated curves and are presented to the nearest 0.1 point to permit accurate reproduction of those curves. Since all converted hardness values must be considered approximate, however, all converted Rockwell hardness numbers shall be rounded to the nearest whole number.

15.2 *Hardness Testing:*

15.2.1 If the product specification permits alternative hardness testing to determine conformance to a specified hardness requirement, the conversions listed in Tables 2A, 2B, 2C, and 2D shall be used.

15.2.2 When recording converted hardness numbers, the measured hardness and test scale shall be indicated in parentheses, for example: 353 HB (38 HRC). This means that a hardness value of 38 was obtained using the Rockwell C scale and converted to a Brinell hardness of 353.

16. Brinell Test

16.1 *Description:*

16.1.1 A specified load is applied to a flat surface of the specimen to be tested, through a hard ball of specified diameter. The average diameter of the indentation is used as a basis for calculation of the Brinell hardness number. The quotient of the applied load divided by the area of the surface of the indentation, which is assumed to be spherical, is termed the Brinell hardness number (HB) in accordance with the following equation:

$$\mathrm{HB} = P/[(\pi D/2)(D - \sqrt{D^2 - d^2})]$$

where:

HB = Brinell hardness number,
P = applied load, kgf,
D = diameter of the steel ball, mm, and
d = average diameter of the indentation, mm.

NOTE 11 — The Brinell hardness number is more conveniently secured from standard tables such as Table 3 which show numbers corresponding to the various indentation diameters, usually in increments of 0.05 mm.

NOTE 12 — In Test Method E 10, the values are stated in SI units whereas in this section, kg/m units are used.

16.1.2 The standard Brinell test using a 10-mm ball employs a 3000-kgf load for hard materials and a 1500 or 500-kgf load for thin sections or soft materials (see Annex A2 on Steel Tubular Products). Other loads and different size indentors may be used when specified. In recording hardness values, the diameter of the ball and the load must be stated except when a 10-mm ball and 3000-kgf load are used.

16.1.3 A range of hardness can properly be specified only for quenched and tempered or normalized and tempered material. For annealed material a maximum figure only should be specified. For normalized material a minimum or a maximum hardness may be specified by agreement. In general, no hardness requirements should be applied to untreated material.

16.1.4 Brinell hardness may be required when tensile properties are not specified.

16.2 *Apparatus* — Equipment shall meet the following requirements:

16.2.1 *Testing Machine* — A Brinell hardness testing machine is acceptable for use over a loading range within which its load measuring device is accurate to ±1%.

16.2.2 *Measuring Microscope* — The divisions of the micrometer scale of the microscope or other measuring devices used for the measurement of the diameter of the indentations shall be such as to permit the direct measurement of the diameter to 0.1 mm and the estimation of the diameter to 0.05 mm.

NOTE 13 — This requirement applies to the construction of the microscope only and is not a requirement for measurement of the indentation. See 16.4.3.

16.2.3 *Standard Ball* — The standard ball for Brinell hardness testing is 10 mm (0.3937 in.) in diameter with a deviation from this value of not more than 0.005 mm (0.0004 in.) in any diameter. A ball suitable for use must not show a permanent change in diameter greater than 0.01 mm (0.0004 in.) when pressed with a force of 3000 kgf against the test specimen.

16.3 *Test Specimen* — Brinell hardness tests are made on prepared areas and sufficient metal must be removed from the surface to eliminate decarburized metal and other surface irregularities. The thickness of the piece tested must be such that no bulge or other marking showing the effect of the load appears on the side of the piece opposite the indentation.

16.4 *Procedure:*

16.4.1 It is essential that the applicable product specifications state clearly the position at which Brinell hardness indentations are to be made and the number of such indentations required. The distance of the center of the indentation from the edge of the specimen or edge of another indentation must be at least two and one-half times the diameter of the indentation.

16.4.2 Apply the load for a minimum of 15 s.

16.4.3 Measure two diameters of the indentation at right angles to the nearest 0.1 mm, estimate to the nearest 0.05 mm, and average to the nearest 0.05 mm. If the two diameters differ by more than 0.1 mm, discard the readings and make a new indentation.

16.4.4 Do not use a steel ball on steels having a hardness over 450 HB nor a carbide ball over 650 HB. The Brinell hardness test is not recommended for materials having a hardness over 650 HB.

16.4.4.1 If a ball is used in a test of a specimen which shows a Brinell hardness number greater than the limit for the ball as detailed in 16.4.4, the ball shall be either discarded and replaced with a new ball or remeasured to ensure conformance with the requirements of Test Method E 10.

16.5 *Detailed Procedure* — For detailed requirements of this test, reference shall be made to the latest revision of Test Method E 10.

17. Rockwell Test

17.1 *Description:*

17.1.1 In this test a hardness value is obtained by determining the depth of penetration of a diamond point or a steel ball into the specimen under certain arbitrarily fixed conditions. A minor load of 10 kgf is first applied which causes an initial penetration, sets the penetrator on the material and holds it in position. A major load which depends on the scale being used is applied increasing the depth of indentation. The major load is removed and, with the minor load still acting, the Rockwell number, which is proportional to the difference in penetration between the major and minor loads is determined; this is usually done by the machine and shows on a dial, digital display, printer, or other device. This is an arbitrary number which increases with increasing hardness. The scales most frequently used are as follows:

Scale Symbol	Penetrator	Major Load, kgf	Minor Load, kgf
B	1/16 in. steel ball	100	10
C	Diamond brale	150	10

17.1.2 Rockwell superficial hardness machines are used for the testing of very thin steel or thin surface layers. Loads of 15, 30, or 45 kgf are applied on a hardened steel ball or diamond penetrator, to cover the same range of hardness values as for the heavier loads. The superficial hardness scales are as follows:

Scale Symbol	Penetrator	Major Load, kgf	Minor Load, kgf
15T	1/16 in. steel ball	15	3
30T	1/16 in. steel ball	30	3
45T	1/16 in. steel ball	45	3
15N	Diamond brale	15	3
30N	Diamond brale	30	3
45N	Diamond brale	45	3

17.2 *Reporting Hardness* — In recording hardness values, the hardness number shall always precede the scale symbol, for example: 96 HRB, 40 HRC, 75 HR15N, or 77 HR30T.

17.3 *Test Blocks* — Machines should be checked to make certain they are in good order by means of standardized Rockwell test blocks.

17.4 *Detailed Procedure* — For detailed requirements of this test, reference shall be made to the latest revision of Test Methods E 18.

18. Portable Hardness Test

18.1 Although the use of the standard, stationary Brinell or Rockwell hardness tester is generally preferred, it is not always possible to perform the hardness test using such equipment due to the part size or location. In this event, hardness testing using portable equipment as described in Practice A 833 to Test Method E 110 shall be used.

CHARPY IMPACT TESTING

19. Summary

19.1 A Charpy V-notch impact test is a dynamic test in which a notched specimen is struck and broken by a single blow in a specially designed testing machine. The measured test values may be the energy absorbed, the percentage shear fracture, the lateral expansion opposite the notch, or a combination thereof.

19.2 Testing temperatures other than room (ambient) temperature often are specified in product or general requirement specifications (hereinafter referred to as the specification). Although the testing temperature is sometimes related to the expected service temperature, the two temperatures need not be identical.

20. Significance and Use

20.1 *Ductile vs. Brittle Behavior*—Body-centered-cubic or ferritic alloys exhibit a significant transition in behavior when impact tested over a range of temperatures. At temperatures above transition, impact specimens fracture by a ductile (usually microvoid coalescence) mechanism, absorbing relatively large amounts of energy. At lower temperatures, they fracture in a brittle (usually cleavage) manner absorbing less energy. Within the transition range, the fracture will generally be a mixture of areas of ductile fracture and brittle fracture.

20.2 The temperature range of the transition from one type of behavior to the other varies according to the material being tested. This transition behavior may be defined in various ways for specification purposes.

20.2.1 The specification may require a minimum test result for absorbed energy, fracture appearance, lateral expansion, or a combination thereof, at a specified test temperature.

20.2.2 The specification may require the determination of the transition temperature at which either the absorbed energy or fracture appearance attains a specified level when testing is performed over a range of temperatures.

20.3 Further information on the significance of impact testing appears in Annex A5.

21. Apparatus

21.1 *Testing Machines:*

21.1.1 A Charpy impact machine is one in which a notched specimen is broken by a single blow of a freely swinging pendulum. The pendulum is released from a fixed height. Since the height to which the pendulum is raised prior to its swing, and the mass of the pendulum are known, the energy of the blow is predetermined. A means is provided to indicate the energy absorbed in breaking the specimen.

21.1.2 The other principal feature of the machine is a fixture (See Fig. 10) designed to support a test specimen as a simple beam at a precise location. The fixture is arranged so that the notched face of the specimen is vertical. The pendulum strikes the other vertical face directly opposite the notch. The dimensions of the specimen supports and striking edge shall conform to Fig. 10.

21.1.3 Charpy machines used for testing steel generally have capacities in the 220 to 300 ft·lbf (300 to 400 J) energy range. Sometimes machines of lesser capacity are used; however, the capacity of the machine should be substantially in excess of the absorbed energy of the specimens (see Test Methods E 23). The linear velocity at the point of impact should be in the range of 16 to 19 ft/s (4.9 to 5.8 m/s).

21.2 *Temperature Media:*

21.2.1 For testing at other than room temperature, it is necessary to condition the Charpy specimens in media at controlled temperatures.

21.2.2 Low temperature media usually are chilled fluids (such as water, ice plus water, dry ice plus organic solvents, or liquid nitrogen) or chilled gases.

21.2.3 Elevated temperature media are usually heated liquids such as mineral or silicone oils. Circulating air ovens may be used.

21.3 *Handling Equipment* — Tongs, especially adapted to fit the notch in the impact specimen, normally are used for removing the specimens from the medium and placing them on the anvil (refer to Test Methods E 23). In cases where the machine fixture does not provide for automatic centering of the test specimen, the tongs may be precision machined to provide centering.

22. Sampling and Number of Specimens

22.1 *Sampling:*

22.1.1 Test location and orientation should be addressed by the specifications. If not, for wrought products, the test location shall be the same as that for the tensile specimen and the orientation shall be longitudinal with the notch perpendicular to the major surface of the product being tested.

22.1.2 *Number of Specimens:*

22.1.2.1 A Charpy impact test consists of all specimens taken from a single test coupon or test location.

22.1.2.2 When the specification calls for a minimum average test result, three specimens shall be tested.

22.1.2.3 When the specification requires determination of a transition temperature, eight to twelve specimens are usually needed.

22.2 *Type and Size:*

22.2.1 Use a standard size Charpy V-notch specimen (Type A) as shown in Fig. 11, except as allowed in 22.2.2.

22.2.2 *Subsized Specimens.*

22.2.2.1 For flat material less than $^{7}/_{16}$ in. (11 mm) thick, or when the absorbed energy is expected to exceed 80% of full scale, use standard subsize test specimens.

22.2.2.2 For tubular materials tested in the transverse direction, where the relationship between diameter and wall thickness does not permit a standard full-size specimen, use standard subsize test specimens or standard size specimens containing outer diameter (OD) curvature as follows:

(1) Standard size specimens and subsize specimens may contain the original OD surface of the tubular product as shown in Fig. 12. All other dimensions shall comply with the requirements of Fig. 11.

NOTE 13 — For materials with toughness levels in excess of about 50 ft-lbs, specimens containing the original OD surface may yield values in excess of those resulting from the use of conventional Charpy specimens.

22.2.2.3 If a full-size specimen cannot be prepared, the largest feasible standard subsize specimen shall be prepared. The specimens shall be machined so that the specimen does not include material nearer to the surface than 0.020 in. (0.5 mm).

22.2.2.4 Tolerances for standard subsize specimens are shown in Fig. 11. Standard subsize test specimen sizes are: 10 × 7.5 mm, 10 × 6.7 mm, 10 × 5 mm, 10 × 3.3 mm, and 10 × 2.5 mm.

22.2.2.5 Notch the narrow face of the specimens so that the notch is perpendicular to the 10 mm wide face.

22.3 *Notch Preparation* — The machining of the notch is critical, as it has been demonstrated that extremely minor variations in notch radius and profile, or tool marks at the bottom of the notch may result in erratic test data. (See Annex A5.)

23. Calibration

23.1 *Accuracy and Sensitivity* — Calibrate and adjust Charpy impact machines in accordance with the requirements of Test Methods E 23.

24. Conditioning—Temperature Control

24.1 When a specific test temperature is required by the specification or purchaser, control the temperature of the heating or cooling medium within ±2°F (1°C) because the effect of variations in temperature on Charpy test results can be very great.

NOTE 14 — For some steels there may not be a need for this restricted temperature, for example, austenitic steels.

NOTE 15 — Because the temperature of a testing laboratory often varies from 60 to 90°F (15 to 32°C) a test conducted at "room temperature" might be conducted at any temperature in this range.

25. Procedure

25.1 *Temperature:*

25.1.1 Condition the specimens to be broken by holding them in the medium at test temperature for at least 5 min in liquid media and 30 min in gaseous media.

25.1.2 Prior to each test, maintain the tongs for handling test specimens at the same temperature as the specimen so as not to affect the temperature at the notch.

25.2 *Positioning and Breaking Specimens:*

25.2.1 Carefully center the test specimen in the anvil and release the pendulum to break the specimen.

25.2.2 If the pendulum is not released within 5 s after removing the specimen from the conditioning medium, do not break the specimen. Return the specimen to the conditioning medium for the period required in 25.1.1.

25.3 *Recovering Specimens* — In the event that fracture appearance or lateral expansion must be determined, recover the matched pieces of each broken specimen before breaking the next specimen.

25.4 *Individual Test Values:*

25.4.1 *Impact energy* — Record the impact energy absorbed to the nearest ft·lbf (J).

25.4.2 *Fracture Appearance:*

25.4.2.1 Determine the percentage of shear fracture area by any of the following methods:

(1) Measure the length and width of the brittle portion of the fracture surface, as shown in Fig. 13 and determine the percent shear area from either Table 4 or 5 depending on the units of measurement.

(2) Compare the appearance of the fracture of the specimen with a fracture appearance chart as shown in Fig. 14.

(3) Magnify the fracture surface and compare it to a precalibrated overlay chart or measure the percent shear fracture area by means of a planimeter.

(4) Photograph the fractured surface at a suitable magnification and measure the percent shear fracture area by means of a planimeter.

25.4.2.2 Determine the individual fracture appearance values to the nearest 5% shear fracture and record the value.

25.4.3 *Lateral Expansion:*

25.4.3.1 Lateral expansion is the increase in specimen width, measured in thousandths of an inch (mils), on the compression side, opposite the notch of the fractured Charpy V-notch specimen as shown in Fig. 15.

25.4.3.2 Examine each specimen half to ascertain that the protrusions have not been damaged by contacting the anvil, machine mounting surface, and so forth. Discard such samples since they may cause erroneous readings.

25.4.3.3 Check the sides of the specimens perpendicular to the notch to ensure that no burrs were formed on the sides during impact testing. If burrs exist, remove them carefully by rubbing on emery cloth or similar abrasive surface, making sure that the protrusions being measured are not rubbed during the removal of the burr.

25.4.3.4 Measure the amount of expansion on each side of each half relative to the plane defined by the undeformed portion of the side of the specimen using a gage similar to that shown in Figs. 16 and 17.

25.4.3.5 Since the fracture path seldom bisects the point of maximum expansion on both sides of a specimen, the sum of the larger values measured for each side is the value of the test. Arrange the halves of one specimen so that compression sides are facing each other. Using the gage, measure the protrusion on each half specimen, ensuring that the same side of the

specimen is measured. Measure the two broken halves individually. Repeat the procedure to measure the protrusions on the opposite side of the specimen halves. The larger of the two values for each side is the expansion of that side of the specimen.

25.4.3.6 Measure the individual lateral expansion values to the nearest mil (0.025 mm) and record the values.

26. Interpretation of Test Result

26.1 When the acceptance criterion of any impact test is specified to be a minimum average value at a given temperature, the test result shall be the average (arithmetic mean) of the individual test values of three specimens from one test location.

26.1.1 When a minimum average test result is specified:

26.1.1.1 The test result is acceptable when all of the below are met:

(1) The test result equals or exceeds the specified minimum average (given in the specification),

(2) The individual test value for not more than one specimen measures less than the specified minimum average, and

(3) The individual test value for any specimen measures not less than two-thirds of the specified minimum average.

26.1.1.2 If the acceptance requirements of 26.1.1.1 are not met, perform one retest of three additional specimens from the same test location. Each individual test value of the retested specimens shall be equal to or greater than the specified minimum average value.

26.2 *Test Specifying a Minimum Transition Temperature:*

26.2.1 *Definition of Transition Temperature* — For specification purposes, the transition temperature is the temperature at which the designated material test value equals or exceeds a specified minimum test value.

26.2.2 *Determination of Transition Temperature:*

26.2.2.1 Break one specimen at each of a series of temperatures above and below the anticipated transition temperature using the procedures in Section 25. Record each test temperature to the nearest 1°F (0.5°C).

26.2.2.2 Plot the individual test results (ft·lbf or percent shear) as the ordinate versus the corresponding test temperature as the abscissa and construct a best-fit curve through the plotted data points.

26.2.2.3 If transition temperature is specified as the temperature at which a test value is achieved, determine the temperature at which the plotted curve intersects the specified test value by graphical interpolation (extrapolation is not permitted). Record this transition temperature to the nearest 5°F (3°C). If the tabulated test results clearly indicate a transition temperature lower than specified, it is not necessary to plot the data. Report the lowest test temperature for which test value exceeds the specified value.

26.2.2.4 Accept the test result if the determined transition temperature is equal to or lower than the specified value.

26.2.2.5 If the determined transition temperature is higher than the specified value, but not more than 20°F (l2°C) higher than the specified value, test sufficient samples in accordance with Section 25 to plot two additional curves. Accept the test results if the temperatures determined from both additional tests are equal to or lower than the specified value.

26.3 When subsize specimens are permitted or necessary, or both, modify the specified test requirement according to Table 6 or test temperature according to ASME Boiler and Pressure Vessel Code, Table UG-84.2, or both. Greater energies or lower test temperatures may be agreed upon by purchaser and supplier.

27. Records

27.1 The test record should contain the following information as appropriate:

27.1.1 Full description of material tested (that is, specification number, grade, class or type, size, heat number).

27.1.2 Specimen orientation with respect to the material axis.

27.1.3 Specimen size.

27.1.4 Test temperature and individual test value for each specimen broken, including initial tests and retests.

27.1.5 Test results.

27.1.6 Transition temperature and criterion for its determination, including initial tests and retests.

28. Report

28.1 The specification should designate the information to be reported.

29. Keywords

29.1 bend test; Brinell hardness; charpy impact test; elongation; FATT (Fracture Appearance Transition Temperature); hardness test; portable hardness; reduction of area; Rockwell hardness; tensile strength; tension test; yield strength

TABLE 1
MULTIPLYING FACTORS TO BE USED FOR VARIOUS DIAMETERS OF ROUND TEST SPECIMENS

Standard Specimen			Small Size Specimens Proportional to Standard					
0.500 in. Round			0.350 in. Round			0.250 in. Round		
Actual Diameter, in.	Area, in.^{2}	Multiplying Factor	Actual Diameter, in.	Area, in.^{2}	Multiplying Factor	Actual Diameter, in.	Area, in.^{2}	Multiplying Factor
0.490	0.1886	5.30	0.343	0.0924	10.82	0.245	0.0471	21.21
0.491	0.1893	5.28	0.344	0.0929	10.76	0.246	0.0475	21.04
0.492	0.1901	5.26	0.345	0.0935	10.70	0.247	0.0479	20.87
0.493	0.1909	5.24	0.346	0.0940	10.64	0.248	0.0483	20.70
0.494	0.1917	5.22	0.347	0.0946	10.57	0.249	0.0487	20.54
0.495	0.1924	5.20	0.348	0.0951	10.51	0.250	0.0491	20.37
0.496	0.1932	5.18	0.349	0.0957	10.45	0.251	0.0495	20.21
							(0.05)[A]	(20.0)[A]
0.497	0.1940	5.15	0.350	0.0962	10.39	0.252	0.0499	20.05
							(0.05)[A]	(20.0)[A]
0.498	0.1948	5.13	0.351	0.0968	10.33	0.253	0.0503	19.89
							(0.05)[A]	(20.0)[A]
0.499	0.1956	5.11	0.352	0.0973	10.28	0.254	0.0507	19.74
0.500	0.1963	5.09	0.353	0.0979	10.22	0.255	0.0511	19.58
0.501	0.1971	5.07	0.354	0.0984	10.16			
0.502	0.1979	5.05	0.355	0.0990	10.10			
0.503	0.1987	5.03	0.356	0.0995	10.05			
				(0.1)[A]	(10.0)[A]			
0.504	0.1995	5.01	0.357	0.1001	9.99			
	(0.2)[A]	(5.0)[A]		(0.1)[A]	(10.0)[A]			
0.505	0.2003	4.99						
	(0.2)[A]	(5.0)[A]						
0.506	0.2011	4.97						
	(0.2)[A]	(5.0)[A]						
0.507	0.2019	4.95						
0.508	0.2027	4.93						
0.509	0.2035	4.91						
0.510	0.2043	4.90						

[A] The values in parentheses may be used for ease in calculation of stresses, in pounds per square inch, as permitted in Note 5 of Fig. 4.

TABLE 2A
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NONAUSTENITIC STEELS[A]
(ROCKWELL C TO OTHER HARDNESS NUMBERS)

					Rockwell Superficial Hardness			
Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-kgf Load, and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	15N Scale, 15-kgf Load, Diamond Penetrator	30N Scale 30-kgf Load, Diamond Penetrator	45N Scale, 45-kgf Load, Diamond Penetrator	Approximate Tensile Strength, ksi (MPa)
68	940	. . .	920	85.6	93.2	84.4	75.4	. . .
67	900	. . .	895	85.0	92.9	83.6	74.2	. . .
66	865	. . .	870	84.5	92.5	82.8	73.3	. . .
65	832	739	846	83.9	92.2	81.9	72.0	. . .
64	800	722	822	83.4	91.8	81.1	71.0	. . .
63	772	706	799	82.8	91.4	80.1	69.9	. . .
62	746	688	776	82.3	91.1	79.3	68.8	. . .
61	720	670	754	81.8	90.7	78.4	67.7	. . .
60	697	654	732	81.2	90.2	77.5	66.6	. . .
59	674	634	710	80.7	89.8	76.6	65.5	351 (2420)
58	653	615	690	80.1	89.3	75.7	64.3	338 (2330)
57	633	595	670	79.6	88.9	74.8	63.2	325 (2240)
56	613	577	650	79.0	88.3	73.9	62.0	313 (2160)
55	595	560	630	78.5	87.9	73.0	60.9	301 (2070)
54	577	543	612	78.0	87.4	72.0	59.8	292 (2010)
53	560	525	594	77.4	86.9	71.2	58.6	283 (1950)
52	544	512	576	76.8	86.4	70.2	57.4	273 (1880)
51	528	496	558	76.3	85.9	69.4	56.1	264 (1820)
50	513	482	542	75.9	85.5	68.5	55.0	255 (1760)
49	498	468	526	75.2	85.0	67.6	53.8	246 (1700)
48	484	455	510	74.7	84.5	66.7	52.5	238 (1640)
47	471	442	495	74.1	83.9	65.8	51.4	229 (1580)
46	458	432	480	73.6	83.5	64.8	50.3	221 (1520)
45	446	421	466	73.1	83.0	64.0	49.0	215 (1480)
44	434	409	452	72.5	82.5	63.1	47.8	208 (1430)
43	423	400	438	72.0	82.0	62.2	46.7	201 (1390)
42	412	390	426	71.5	81.5	61.3	45.5	194 (1340)
41	402	381	414	70.9	80.9	60.4	44.3	188 (1300)
40	392	371	402	70.4	80.4	59.5	43.1	182 (1250)
39	382	362	391	69.9	79.9	58.6	41.9	177 (1220)
38	372	353	380	69.4	79.4	57.7	40.8	171 (1180)
37	363	344	370	68.9	78.8	56.8	39.6	166 (1140)
36	354	336	360	68.4	78.3	55.9	38.4	161 (1110)
35	345	327	351	67.9	77.7	55.0	37.2	156 (1080)
34	336	319	342	67.4	77.2	54.2	36.1	152 (1050)
33	327	311	334	66.8	76.6	53.3	34.9	149 (1030)
32	318	301	326	66.3	76.1	52.1	33.7	146 (1010)
31	310	294	318	65.8	75.6	51.3	32.5	141 (970)
30	302	286	311	65.3	75.0	50.4	31.3	138 (950)
29	294	279	304	64.6	74.5	49.5	30.1	135 (930)
28	286	271	297	64.3	73.9	48.6	28.9	131 (900)
27	279	264	290	63.8	73.3	47.7	27.8	128 (880)
26	272	258	284	63.3	72.8	46.8	26.7	125 (860)
25	266	253	278	62.8	72.2	45.9	25.5	123 (850)
24	260	247	272	62.4	71.6	45.0	24.3	119 (820)
23	254	243	266	62.0	71.0	44.0	23.1	117 (810)
22	248	237	261	61.5	70.5	43.2	22.0	115 (790)
21	243	231	256	61.0	69.9	42.3	20.7	112 (770)
20	238	226	251	60.5	69.4	41.5	19.6	110 (760)

[A] This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 2B
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NONAUSTENITIC STEELS[A]
(ROCKWELL B TO OTHER HARDNESS NUMBERS)

Rockwell B Scale, 100-kgf Load 1/16-in. (1.588-mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-kgf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell F Scale, 60-kgf Load, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
						15T Scale, 15-kgf Load, 1/16-in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1/16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1/16-in. (1.588-mm) Ball	
100	240	240	251	61.5	. . .	93.1	83.1	72.9	116 (800)
99	234	234	246	60.9	. . .	92.8	82.5	71.9	114 (785)
98	228	228	241	60.2	. . .	92.5	81.8	70.9	109 (750)
97	222	222	236	59.5	. . .	92.1	81.1	69.9	104 (715)
96	216	216	231	58.9	. . .	91.8	80.4	68.9	102 (705)
95	210	210	226	58.3	. . .	91.5	79.8	67.9	100 (690)
94	205	205	221	57.6	. . .	91.2	79.1	66.9	98 (675)
93	200	200	216	57.0	. . .	90.8	78.4	65.9	94 (650)
92	195	195	211	56.4	. . .	90.5	77.8	64.8	92 (635)
91	190	190	206	55.8	. . .	90.2	77.1	63.8	90 (620)
90	185	185	201	55.2	. . .	89.9	76.4	62.8	89 (615)
89	180	180	196	54.6	. . .	89.5	75.8	61.8	88 (605)
88	176	176	192	54.0	. . .	89.2	75.1	60.8	86 (590)
87	172	172	188	53.4	. . .	88.9	74.4	59.8	84 (580)
86	169	169	184	52.8	. . .	88.6	73.8	58.8	83 (570)
85	165	165	180	52.3	. . .	88.2	73.1	57.8	82 (565)
84	162	162	176	51.7	. . .	87.9	72.4	56.8	81 (560)
83	159	159	173	51.1	. . .	87.6	71.8	55.8	80 (550)
82	156	156	170	50.6	. . .	87.3	71.1	54.8	77 (530)
81	153	153	167	50.0	. . .	86.9	70.4	53.8	73 (505)
80	150	150	164	49.5	. . .	86.6	69.7	52.8	72 (495)
79	147	147	161	48.9	. . .	86.3	69.1	51.8	70 (485)
78	144	144	158	48.4	. . .	86.0	68.4	50.8	69 (475)
77	141	141	155	47.9	. . .	85.6	67.7	49.8	68 (470)
76	139	139	152	47.3	. . .	85.3	67.1	48.8	67 (460)
75	137	137	150	46.8	99.6	85.0	66.4	47.8	66 (455)
74	135	135	147	46.3	99.1	84.7	65.7	46.8	65 (450)
73	132	132	145	45.8	98.5	84.3	65.1	45.8	64 (440)
72	130	130	143	45.3	98.0	84.0	64.4	44.8	63 (435)
71	127	127	141	44.8	97.4	83.7	63.7	43.8	62 (425)
70	125	125	139	44.3	96.8	83.4	63.1	42.8	61 (420)
69	123	123	137	43.8	96.2	83.0	62.4	41.8	60 (415)
68	121	121	135	43.3	95.6	82.7	61.7	40.8	59 (405)
67	119	119	133	42.8	95.1	82.4	61.0	39.8	58 (400)
66	117	117	131	42.3	94.5	82.1	60.4	38.7	57 (395)
65	116	116	129	41.8	93.9	81.8	59.7	37.7	56 (385)
64	114	114	127	41.4	93.4	81.4	59.0	36.7	. . .
63	112	112	125	40.9	92.8	81.1	58.4	35.7	. . .
62	110	110	124	40.4	92.2	80.8	57.7	34.7	. . .
61	108	108	122	40.0	91.7	80.5	57.0	33.7	. . .
60	107	107	120	39.5	91.1	80.1	56.4	32.7	. . .
59	106	106	118	39.0	90.5	79.8	55.7	31.7	. . .
58	104	104	117	38.6	90.0	79.5	55.0	30.7	. . .
57	103	103	115	38.1	89.4	79.2	54.4	29.7	. . .
56	101	101	114	37.7	88.8	78.8	53.7	28.7	. . .
55	100	100	112	37.2	88.2	78.5	53.0	27.7	. . .
54	. . .	. . .	111	36.8	87.7	78.2	52.4	26.7	. . .
53	. . .	. . .	110	36.3	86.5	77.9	51.7	25.7	. . .
52	. . .	. . .	109	35.9	86.0	77.5	51.0	24.7	. . .
51	. . .	. . .	108	35.5	85.4	77.2	50.3	23.7	. . .
50	. . .	. . .	107	35.0	84.8	76.9	49.7	22.7	. . .

TABLE 2B (CONT'D)
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR NONAUSTENITIC STEELS[A]
(ROCKWELL B TO OTHER HARDNESS NUMBERS)

Rockwell B Scale, 100-kgf Load 1/16-in. (1.588-mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-kgf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell F Scale, 60-kgf Load, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
						15T Scale, 15-kgf Load, 1/16-in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1/16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1/16-in. (1.588-mm) Ball	
49	...	...	106	34.6	84.3	76.6	49.0	21.7	...
48	...	...	105	34.1	83.7	76.2	48.3	20.7	...
47	...	...	104	33.7	83.1	75.9	47.7	19.7	...
46	...	...	103	33.3	...	75.6	47.0	18.7	...
45	...	...	102	32.9	82.6	75.3	46.3	17.7	...
44	...	...	101	32.4	82.0	74.9	45.7	16.7	...
43	...	...	100	32.0	81.4	74.6	45.0	15.7	...
42	...	...	99	31.6	80.8	74.3	44.3	14.7	...
41	...	...	98	31.2	80.3	74.0	43.7	13.6	...
40	...	...	97	30.7	79.7	73.6	43.0	12.6	...
39	...	...	96	30.3	79.1	73.3	42.3	11.6	...
38	...	...	95	29.9	78.6	73.0	41.6	10.6	...
37	...	...	94	29.5	78.0	72.7	41.0	9.6	...
36	...	...	93	29.1	77.4	72.3	40.3	8.6	...
35	...	...	92	28.7	76.9	72.0	39.6	7.6	...
34	...	...	91	28.2	76.3	71.7	39.0	6.6	...
33	...	...	90	27.8	75.7	71.4	38.3	5.6	...
32	...	...	89	27.4	75.2	71.0	37.6	4.6	...
31	...	...	88	27.0	74.6	70.7	37.0	3.6	...
30	...	...	87	26.6	74.0	70.4	36.3	2.6	...

[A] This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 2C
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR AUSTENITIC STEELS
(ROCKWELL C TO OTHER HARDNESS NUMBERS)

		Rockwell Superficial Hardness		
Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	15N Scale, 15-kgf Load, Diamond Penetrator	30N Scale, 30-kgf Load, Diamond Penetrator	45N Scale, 45-kgf Load, Diamond Penetrator
48	74.4	84.1	66.2	52.1
47	73.9	83.6	65.3	50.9
46	73.4	83.1	64.5	49.8
45	72.9	82.6	63.6	48.7
44	72.4	82.1	62.7	47.5
43	71.9	81.6	61.8	46.4
42	71.4	81.0	61.0	45.2
41	70.9	80.5	60.1	44.1
40	70.4	80.0	59.2	43.0
39	69.9	79.5	58.4	41.8
38	69.3	79.0	57.5	40.7
37	68.8	78.5	56.6	39.6
36	68.3	78.0	55.7	38.4
35	67.8	77.5	54.9	37.3
34	67.3	77.0	54.0	36.1
33	66.8	76.5	53.1	35.0
32	66.3	75.9	52.3	33.9
31	65.8	75.4	51.4	32.7
30	65.3	74.9	50.5	31.6
29	64.8	74.4	49.6	30.4
28	64.3	73.9	48.8	29.3
27	63.8	73.4	47.9	28.2
26	63.3	72.9	47.0	27.0
25	62.8	72.4	46.2	25.9
24	62.3	71.9	45.3	24.8
23	61.8	71.3	44.4	23.6
22	61.3	70.8	43.5	22.5
21	60.8	70.3	42.7	21.3
20	60.3	69.8	41.8	20.2

TABLE 2D
APPROXIMATE HARDNESS CONVERSION NUMBERS FOR AUSTENITIC STEELS
(ROCKWELL B TO OTHER HARDNESS NUMBERS)

Rockwell B Scale, 100-kgf Load, 1/16 in. (1.588-mm) Ball	Brinell Indentation Diameter, mm	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
				15T Scale, 15-kgf Load, 1/16-in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1/16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1/16-in. (1.588-mm) Ball
100	3.79	256	61.5	91.5	80.4	70.2
99	3.85	248	60.9	91.2	79.7	69.2
98	3.91	240	60.3	90.8	79.0	68.2
97	3.96	233	59.7	90.4	78.3	67.2
96	4.02	226	59.1	90.1	77.7	66.1
95	4.08	219	58.5	89.7	77.0	65.1
94	4.14	213	58.0	89.3	76.3	64.1
93	4.20	207	57.4	88.9	75.6	63.1
92	4.24	202	56.8	88.6	74.9	62.1
91	4.30	197	56.2	88.2	74.2	61.1
90	4.35	192	55.6	87.8	73.5	60.1
89	4.40	187	55.0	87.5	72.8	59.0
88	4.45	183	54.5	87.1	72.1	58.0
87	4.51	178	53.9	86.7	71.4	57.0
86	4.55	174	53.3	86.4	70.7	56.0
85	4.60	170	52.7	86.0	70.0	55.0
84	4.65	167	52.1	85.6	69.3	54.0
83	4.70	163	51.5	85.2	68.6	52.9
82	4.74	160	50.9	84.9	67.9	51.9
81	4.79	156	50.4	84.5	67.2	50.9
80	4.84	153	49.8	84.1	66.5	49.9

TABLE 3
BRINELL HARDNESS NUMBERS[4]
(Ball 10 mm in Diameter, Applied Loads of 500, 1500, and 3000 kgf)

Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number		
	500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load
2.00	*158*	*473*	*945*	2.60	92.6	278	555	3.20	60.5	182	363	3.80	42.4	127	255
2.01	*156*	*468*	*936*	2.61	91.8	276	551	3.21	60.1	180	361	3.81	42.2	127	253
2.02	*154*	*463*	*926*	2.62	91.1	273	547	3.22	59.8	179	359	3.82	42.0	126	252
2.03	*153*	*459*	*917*	2.63	90.4	271	543	3.23	59.4	178	356	3.83	41.7	125	250
2.04	*151*	*454*	*908*	2.64	89.7	269	538	3.24	59.0	177	354	3.84	41.5	125	249
2.05	*150*	*450*	*899*	2.65	89.0	267	534	3.25	58.6	176	352	3.85	41.3	124	248
2.06	*148*	*445*	*890*	2.66	88.4	265	530	3.26	58.3	175	350	3.86	41.1	123	246
2.07	*147*	*441*	*882*	2.67	87.7	263	526	3.27	57.9	174	347	3.87	40.9	123	245
2.08	*146*	*437*	*873*	2.68	87.0	261	522	3.28	57.5	173	345	3.88	40.6	122	244
2.09	*144*	*432*	*865*	2.69	86.4	259	518	3.29	57.2	172	343	3.89	40.4	121	242
2.10	*143*	*428*	*856*	2.70	85.7	257	514	3.30	56.8	170	341	3.90	40.2	121	241
2.11	*141*	*424*	*848*	2.71	85.1	255	510	3.31	56.5	169	339	3.91	40.0	120	240
2.12	*140*	*420*	*840*	2.72	84.4	253	507	3.32	56.1	168	337	3.92	39.8	119	239
2.13	*139*	*416*	*832*	2.73	83.8	251	503	3.33	55.8	167	335	3.93	39.6	119	237
2.14	*137*	*412*	*824*	2.74	83.2	250	499	3.34	55.4	166	333	3.94	39.4	118	236
2.15	*136*	*408*	*817*	2.75	82.6	248	495	3.35	55.1	165	331	3.95	39.1	117	235
2.16	*135*	*404*	*809*	2.76	81.9	246	492	3.36	54.8	164	329	3.96	38.9	117	234
2.17	*134*	*401*	*802*	2.77	81.3	244	488	3.37	54.4	163	326	3.97	38.7	116	232
2.18	*132*	*397*	*794*	2.78	80.8	242	485	3.38	54.1	162	325	3.98	38.5	116	231
2.19	*131*	*393*	*787*	2.79	80.2	240	481	3.39	53.8	161	323	3.99	38.3	115	230
2.20	*130*	*390*	*780*	2.80	79.6	239	477	3.40	53.4	160	321	4.00	38.1	114	229
2.21	*129*	*386*	*772*	2.81	79.0	237	474	3.41	53.1	159	319	4.01	37.9	114	228
2.22	*128*	*383*	*765*	2.82	78.4	235	471	3.42	52.8	158	317	4.02	37.7	113	226
2.23	*126*	*379*	*758*	2.83	77.9	234	467	3.43	52.5	157	315	4.03	37.5	113	225
2.24	*125*	*376*	*752*	2.84	77.3	232	464	3.44	52.2	156	313	4.04	37.3	112	224
2.25	*124*	*372*	*745*	2.85	76.8	230	461	3.45	51.8	156	311	4.05	37.1	111	223
2.26	*123*	*369*	*738*	2.86	76.2	229	457	3.46	51.5	155	309	4.06	37.0	111	222
2.27	*122*	*366*	*732*	2.87	75.7	227	454	3.47	51.2	154	307	4.07	36.8	110	221
2.28	*121*	*363*	*725*	2.88	75.1	225	451	3.48	50.9	153	306	4.08	36.6	110	219
2.29	*120*	*359*	*719*	2.89	74.6	224	448	3.49	50.6	152	304	4.09	36.4	109	218
2.30	*119*	*356*	*712*	2.90	74.1	222	444	3.50	50.3	151	302	4.10	36.2	109	217
2.31	*118*	*353*	*706*	2.91	73.6	221	441	3.51	50.0	150	300	4.11	36.0	108	216
2.32	*117*	*350*	*700*	2.92	73.0	219	438	3.52	49.7	149	298	4.12	35.8	108	215
2.33	*116*	*347*	*694*	2.93	72.5	218	435	3.53	49.4	148	297	4.13	35.7	107	214
2.34	*115*	*344*	*688*	2.94	72.0	216	432	3.54	49.2	147	295	4.14	35.5	106	213
2.35	*114*	*341*	*682*	2.95	71.5	215	429	3.55	48.9	147	293	4.15	35.3	106	212
2.36	*113*	*338*	*676*	2.96	71.0	213	426	3.56	48.6	146	292	4.16	35.1	105	211
2.37	*112*	*335*	*670*	2.97	70.5	212	423	3.57	48.3	145	290	4.17	34.9	105	210
2.38	*111*	*332*	*665*	2.98	70.1	210	420	3.58	48.0	144	288	4.18	34.8	104	209
2.39	*110*	*330*	*659*	2.99	69.6	209	417	3.59	47.7	143	286	4.19	34.6	104	208
2.40	*109*	*327*	*653*	3.00	69.1	207	415	3.60	47.5	142	285	4.20	34.4	103	207
2.41	*108*	*324*	*648*	3.01	68.6	206	412	3.61	47.2	142	283	4.21	34.2	103	205
2.42	*107*	*322*	*643*	3.02	68.2	205	409	3.62	46.9	141	282	4.22	34.1	102	204
2.43	*106*	*319*	*637*	3.03	67.7	203	406	3.63	46.7	140	280	4.23	33.9	102	203
2.44	*105*	*316*	*632*	3.04	67.3	202	404	3.64	46.4	139	278	4.24	33.7	101	202
2.45	*104*	*313*	*627*	3.05	66.8	200	401	3.65	46.1	138	277	4.25	33.6	101	201
2.46	*104*	*311*	*621*	3.06	66.4	199	398	3.66	45.9	138	275	4.26	33.4	100	200
2.47	*103*	*308*	*616*	3.07	65.9	198	395	3.67	45.6	137	274	4.27	33.2	99.7	199
2.48	*102*	*306*	*611*	3.08	65.5	196	393	3.68	45.4	136	272	4.28	33.1	99.2	198
2.49	*101*	*303*	*606*	3.09	65.0	195	390	3.69	45.1	135	271	4.29	32.9	98.8	198

TABLE 3 (CONT'D)
BRINELL HARDNESS NUMBERS[4]
(Ball 10 mm in Diameter, Applied Loads of 500, 1500, and 3000 kgf)

Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number		
	500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load
2.50	100	301	601	3.10	64.6	194	388	3.70	44.9	135	269	4.30	32.8	98.3	197
2.51	99.4	298	597	3.11	64.2	193	385	3.71	44.6	134	268	4.31	32.6	97.8	196
2.52	98.6	296	592	3.12	63.8	191	383	3.72	44.4	133	266	4.32	32.4	97.3	195
2.53	97.8	294	587	3.13	63.3	190	380	3.73	44.1	132	265	4.33	32.3	96.8	194
2.54	97.1	291	582	3.14	62.9	189	378	3.74	43.9	132	263	4.34	32.1	96.4	193
2.55	96.3	289	578	3.15	62.5	188	375	3.75	43.6	131	262	4.35	32.0	95.9	192
2.56	95.5	287	573	3.16	62.1	186	373	3.76	43.4	130	260	4.36	31.8	95.5	191
2.57	94.8	284	569	3.17	61.7	185	370	3.77	43.1	129	259	4.37	31.7	95.0	190
2.58	94.0	282	564	3.18	61.3	184	368	3.78	42.9	129	257	4.38	31.5	94.5	189
2.59	93.3	280	560	3.19	60.9	183	366	3.79	42.7	128	256	4.39	31.4	94.1	188
4.40	31.2	93.6	187	5.05	23.3	69.8	140	5.70	17.8	53.5	107	6.35	*14.0*	*42.0*	*84.0*
4.41	31.1	93.2	186	5.06	23.2	69.5	139	5.71	17.8	53.3	107	6.36	*13.9*	*41.8*	*83.7*
4.42	30.9	92.7	185	5.07	23.1	69.2	138	5.72	17.7	53.1	106	6.37	*13.9*	*41.7*	*83.4*
4.43	30.8	92.3	185	5.08	23.0	68.9	138	5.73	17.6	52.9	106	6.38	*13.8*	*41.5*	*83.1*
4.44	30.6	91.8	184	5.09	22.9	68.6	137	5.74	17.6	52.7	105	6.39	*13.8*	*41.4*	*82.8*
4.45	30.5	91.4	183	5.10	22.8	68.3	137	5.75	17.5	52.5	105	6.40	*13.7*	*41.2*	*82.5*
4.46	30.3	91.0	182	5.11	22.7	68.0	136	5.76	17.4	52.3	105	6.41	*13.7*	*41.1*	*82.2*
4.47	30.2	90.5	181	5.12	22.6	67.7	135	5.77	17.4	52.1	104	6.42	*13.6*	*40.9*	*81.9*
4.48	30.0	90.1	180	5.13	22.5	67.4	135	5.78	17.3	51.9	104	6.43	*13.6*	*40.8*	*81.6*
4.49	29.9	89.7	179	5.14	22.4	67.1	134	5.79	17.2	51.7	103	6.44	*13.5*	*40.6*	*81.3*
4.50	29.8	89.3	179	5.15	22.3	66.9	134	5.80	17.2	51.5	103	6.45	*13.5*	*40.5*	*81.0*
4.51	29.6	88.8	178	5.16	22.2	66.6	133	5.81	17.1	51.3	103	6.46	*13.4*	*40.4*	*80.7*
4.52	29.5	88.4	177	5.17	22.1	66.3	133	5.82	17.0	51.1	102	6.47	*13.4*	*40.2*	*80.4*
4.53	29.3	88.0	176	5.18	22.0	66.0	132	5.83	17.0	50.9	102	6.48	*13.4*	*40.1*	*80.1*
4.54	29.2	87.6	175	5.19	21.9	65.8	132	5.84	16.9	50.7	101	6.49	*13.3*	*39.9*	*79.8*
4.55	29.1	87.2	174	5.20	21.8	65.5	131	5.85	16.8	50.5	101	6.50	*13.3*	*39.8*	*79.6*
4.56	28.9	86.8	174	5.21	21.7	65.2	130	5.86	16.8	50.3	101	6.51	*13.2*	*39.6*	*79.3*
4.57	28.8	86.4	173	5.22	21.6	64.9	130	5.87	16.7	50.2	100	6.52	*13.2*	*39.5*	*79.0*
4.58	28.7	86.0	172	5.23	21.6	64.7	129	5.88	16.7	50.0	99.9	6.53	*13.1*	*39.4*	*78.7*
4.59	28.5	85.6	171	5.24	21.5	64.4	129	5.89	16.6	49.8	99.5	6.54	*13.1*	*39.2*	*78.4*
4.60	28.4	85.4	170	5.25	21.4	64.1	128	5.90	16.5	49.6	99.2	6.55	*13.0*	*39.1*	*78.2*
4.61	28.3	84.8	170	5.26	21.3	63.9	128	5.91	16.5	49.4	98.8	6.56	*13.0*	*38.9*	*78.0*
4.62	28.1	84.4	169	5.27	21.2	63.6	127	5.92	16.4	49.2	98.4	6.57	*12.9*	*38.8*	*77.6*
4.63	28.0	84.0	168	5.28	21.1	63.3	127	5.93	16.3	49.0	98.0	6.58	*12.9*	*38.7*	*77.3*
4.64	27.9	83.6	167	5.29	21.0	63.1	126	5.94	16.3	48.8	97.7	6.59	*12.8*	*38.5*	*77.1*
4.65	27.8	83.3	167	5.30	20.9	62.8	126	5.95	16.2	48.7	97.3	6.60	*12.8*	*38.4*	*76.8*
4.66	27.6	82.9	166	5.31	20.9	62.6	125	5.96	16.2	48.5	96.9	6.61	*12.8*	*38.3*	*76.5*
4.67	27.5	82.5	165	5.32	20.8	62.3	125	5.97	16.1	48.3	96.6	6.62	*12.7*	*38.1*	*76.2*
4.68	27.4	82.1	164	5.33	20.7	62.1	124	5.98	16.0	48.1	96.2	6.63	*12.7*	*38.0*	*76.0*
4.69	27.3	81.8	164	5.34	20.6	61.8	124	5.99	16.0	47.9	95.9	6.64	*12.6*	*37.9*	*75.7*
4.70	27.1	81.4	163	5.35	20.5	61.5	123	6.00	*15.9*	47.7	95.5	6.65	*12.6*	*37.7*	*75.4*
4.71	27.0	81.0	162	5.36	20.4	61.3	123	6.01	*15.9*	47.6	95.1	6.66	*12.5*	*37.6*	*75.2*
4.72	26.9	80.7	161	5.37	20.3	61.0	122	6.02	*15.8*	47.4	94.8	6.67	*12.5*	*37.5*	*74.9*
4.73	26.8	80.3	161	5.38	20.3	60.8	122	6.03	*15.7*	47.2	94.4	6.68	*12.4*	*37.3*	*74.7*
4.74	26.6	79.9	160	5.39	20.2	60.6	121	6.04	*15.7*	47.0	94.1	6.69	*12.4*	*37.2*	*74.4*
4.75	26.5	79.6	159	5.40	20.1	60.3	121	6.05	*15.6*	46.8	93.7	6.70	*12.4*	*37.1*	*74.1*
4.76	26.4	79.2	158	5.41	20.0	60.1	120	6.06	*15.6*	46.7	93.4	6.71	*12.3*	*36.9*	*73.9*
4.77	26.3	78.9	158	5.42	19.9	59.8	120	6.07	*15.5*	46.5	93.0	6.72	*12.3*	*36.8*	*73.6*
4.78	26.2	78.5	157	5.43	19.9	59.6	119	6.08	*15.4*	46.3	92.7	6.73	*12.2*	*36.7*	*73.4*
4.79	26.1	78.2	156	5.44	19.8	59.3	119	6.09	*15.4*	46.2	92.3	6.74	*12.2*	*36.6*	*73.1*

TABLE 3 (CONT'D)
BRINELL HARDNESS NUMBERS[A]
(Ball 10 mm in Diameter, Applied Loads of 500, 1500, and 3000 kgf)

Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number		
	500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load
4.80	25.9	77.8	156	5.45	19.7	59.1	118	6.10	*15.3*	46.0	92.0	6.75	*12.1*	*36.4*	*72.8*
4.81	25.8	77.5	155	5.46	19.6	58.9	118	6.11	*15.3*	45.8	91.7	6.76	*12.1*	*36.3*	*72.6*
4.82	25.7	77.1	154	5.47	19.5	58.6	117	6.12	*15.2*	45.7	91.3	6.77	*12.1*	*36.2*	*72.3*
4.83	25.6	76.8	154	5.48	19.5	58.4	117	6.13	*15.2*	45.5	91.0	6.78	*12.0*	*36.0*	*72.1*
4.84	25.5	76.4	153	5.49	19.4	58.2	116	6.14	*15.1*	45.3	90.6	6.79	*12.0*	*35.9*	*71.8*
4.85	25.4	76.1	152	5.50	19.3	57.9	116	6.15	*15.1*	45.2	90.3	6.80	*11.9*	*35.8*	*71.6*
4.86	25.3	75.8	152	5.51	19.2	57.7	115	6.16	*15.0*	45.0	90.0	6.81	*11.9*	*35.7*	*71.3*
4.87	25.1	75.4	151	5.52	19.2	57.5	115	6.17	*14.9*	44.8	89.6	6.82	*11.8*	*35.5*	*71.1*
4.88	25.0	75.1	150	5.53	19.1	57.2	114	6.18	*14.9*	44.7	89.3	6.83	*11.8*	*35.4*	*70.8*
4.89	24.9	74.8	150	5.54	19.0	57.0	114	6.19	*14.8*	44.5	89.0	6.84	*11.8*	*35.3*	*70.6*
4.90	24.8	74.4	149	5.55	18.9	56.8	114	6.20	*14.7*	44.3	88.7	6.86	*11.7*	*35.2*	*70.4*
4.91	24.7	74.1	148	5.56	18.9	56.6	113	6.21	*14.7*	44.2	88.3	6.86	*11.7*	*35.1*	*70.1*
4.92	24.6	73.8	148	5.57	18.8	56.3	113	6.22	*14.7*	44.0	88.0	6.87	*11.6*	*34.9*	*69.9*
4.93	24.5	73.5	147	5.58	18.7	56.1	112	6.23	*14.6*	43.8	87.7	6.88	*11.6*	*34.8*	*69.6*
4.94	24.4	73.2	146	5.59	18.6	55.9	112	6.24	*14.6*	43.7	87.4	6.89	*11.6*	*34.7*	*69.4*
4.95	24.3	72.8	146	5.60	18.6	55.7	111	6.25	*14.5*	43.5	87.1	6.90	*11.5*	*34.6*	*69.2*
4.96	24.2	72.5	145	5.61	18.5	55.5	111	6.26	*14.5*	43.4	86.7	6.91	*11.5*	*34.5*	*68.9*
4.97	24.1	72.2	144	5.62	18.4	55.2	110	6.27	*14.4*	43.2	86.4	6.92	*11.4*	*34.3*	*68.7*
4.98	24.0	71.9	144	5.63	18.3	55.0	110	6.28	*14.4*	43.1	86.1	6.93	*11.4*	*34.2*	*68.4*
4.99	23.9	71.6	143	5.64	18.3	54.8	110	6.29	*14.3*	42.9	85.8	6.94	*11.4*	*34.1*	*68.2*
5.00	23.8	71.3	143	5.65	18.2	54.6	109	6.30	*14.2*	42.7	85.5	6.95	*11.3*	*34.0*	*68.0*
5.01	23.7	71.0	142	5.66	18.1	54.4	109	6.31	*14.2*	42.6	85.2	6.96	*11.3*	*33.9*	*67.7*
5.02	23.6	70.7	141	5.67	18.1	54.2	108	6.32	*14.1*	42.4	84.9	6.97	*11.3*	*33.8*	*67.5*
5.03	23.5	70.4	141	5.68	18.0	54.0	108	6.33	*14.1*	42.3	84.6	6.98	*11.2*	*33.6*	*67.3*
5.04	23.4	70.1	140	5.69	17.9	53.7	107	6.34	*14.0*	42.1	84.3	6.99	*11.2*	*33.5*	*67.0*

[A] Prepared by the Engineering Mechanics Section, Institute for Standards Technology.

TABLE 4
PERCENT SHEAR FOR MEASUREMENTS MADE IN INCHES

NOTE — Since this table is set up for finite measurements or dimensions *A* and *B*, 100% shear is to be reported when either *A* or *B* is zero.

Dimension *B*, in.	Dimension *A*, in.																
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40
0.05	98	96	95	94	94	93	92	91	90	90	89	88	87	86	85	85	84
0.10	96	92	90	89	87	85	84	82	81	79	77	76	74	73	71	69	68
0.12	95	90	88	86	85	83	81	79	77	75	73	71	69	67	65	63	61
0.14	94	89	86	84	82	80	77	75	73	71	68	66	64	62	59	57	55
0.16	94	87	85	82	79	77	74	72	69	67	64	61	59	56	53	51	48
0.18	93	85	83	80	77	74	72	68	65	62	59	56	54	51	48	45	42
0.20	92	84	81	77	74	72	68	65	61	58	55	52	48	45	42	39	36
0.22	91	82	79	75	72	68	65	61	57	54	50	47	43	40	36	33	29
0.24	90	81	77	73	69	65	61	57	54	50	46	42	38	34	30	27	23
0.26	90	79	75	71	67	62	58	54	50	46	41	37	33	29	25	20	16
0.28	89	77	73	68	64	59	55	50	46	41	37	32	28	23	18	14	10
0.30	88	76	71	66	61	56	52	47	42	37	32	27	23	18	13	9	3
0.31	88	75	70	65	60	55	50	45	40	35	30	25	20	18	10	5	0

TABLE 5
PERCENT SHEAR FOR MEASUREMENTS MADE IN MILLIMETERS

NOTE — Since this table is set up for finite measurements or dimensions *A* and *B*, 100% shear is to be reported when either *A* or *B* is zero.

Dimension *B*, mm	Dimension *A*, mm																		
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
1.0	99	98	98	97	96	96	95	94	94	93	92	92	91	91	90	89	89	88	88
1.5	98	97	96	95	94	93	92	92	91	90	89	88	87	86	85	84	83	82	81
2.0	98	96	95	94	92	91	90	89	88	86	85	84	82	81	80	79	77	76	75
2.5	97	95	94	92	91	89	88	86	84	83	81	80	78	77	75	73	72	70	69
3.0	96	94	92	91	89	87	85	83	81	79	77	76	74	72	70	68	66	64	62
3.5	96	93	91	89	87	85	82	80	78	76	74	72	69	67	65	63	61	58	56
4.0	95	92	90	88	85	82	80	77	75	72	70	67	65	62	60	57	55	52	50
4.5	94	92	89	86	83	80	77	75	72	69	66	63	61	58	55	52	49	46	44
5.0	94	91	88	85	81	78	75	72	69	66	62	59	56	53	50	47	44	41	37
5.5	93	90	86	83	79	76	72	69	66	62	59	55	52	48	45	42	38	35	31
6.0	92	89	85	81	77	74	70	66	62	59	55	51	47	44	40	36	33	29	25
6.5	92	88	84	80	76	72	67	63	59	55	51	47	43	39	35	31	27	23	19
7.0	91	87	82	78	74	69	65	61	56	52	47	43	39	34	30	26	21	17	12
7.5	91	86	81	77	72	67	62	58	53	48	44	39	34	30	25	20	16	11	6
8.0	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0

TABLE 6
CHARPY V-NOTCH TEST ACCEPTANCE CRITERIA FOR VARIOUS SUB-SIZE SPECIMENS

Full Size, 10 by 10 mm		¾ Size, 10 by 7.5 mm		⅔ Size, 10 by 6.7 mm		½ Size, 10 by 5 mm		⅓ Size, 10 by 3.3 mm		¼ Size, 10 by 2.5 mm	
ft · lbf	[J]	ft · lbf	[J]	ft · lbf	[J]	ft · lbf	[J]	ft · lbf	[J]	ft · lbf	[J]
40	[54]	30	[41]	27	[37]	20	[27]	13	[18]	10	[14]
35	[48]	26	[35]	23	[31]	18	[24]	12	[16]	9	[12]
30	[41]	22	[30]	20	[27]	15	[20]	10	[14]	8	[11]
25	[34]	19	[26]	17	[23]	12	[16]	8	[11]	6	[8]
20	[27]	15	[20]	13	[18]	10	[14]	7	[10]	5	[7]
16	[22]	12	[16]	11	[15]	8	[11]	5	[7]	4	[5]
15	[20]	11	[15]	10	[14]	8	[11]	5	[7]	4	[5]
13	[18]	10	[14]	9	[12]	6	[8]	4	[5]	3	[4]
12	[16]	9	[12]	8	[11]	6	[8]	4	[5]	3	[4]
10	[14]	8	[11]	7	[10]	5	[7]	3	[4]	2	[3]
7	[10]	5	[7]	5	[7]	4	[5]	2	[3]	2	[3]

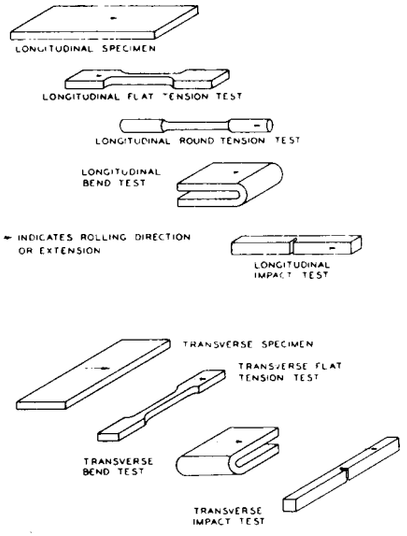


FIG. 1 THE RELATION OF TES COUPONS AND TEST SPERIMENS TO ROLLING DIRECTION OR EXTENSION (APPLICABLE) TO GENERAL WROUGHT PRODUCTS)

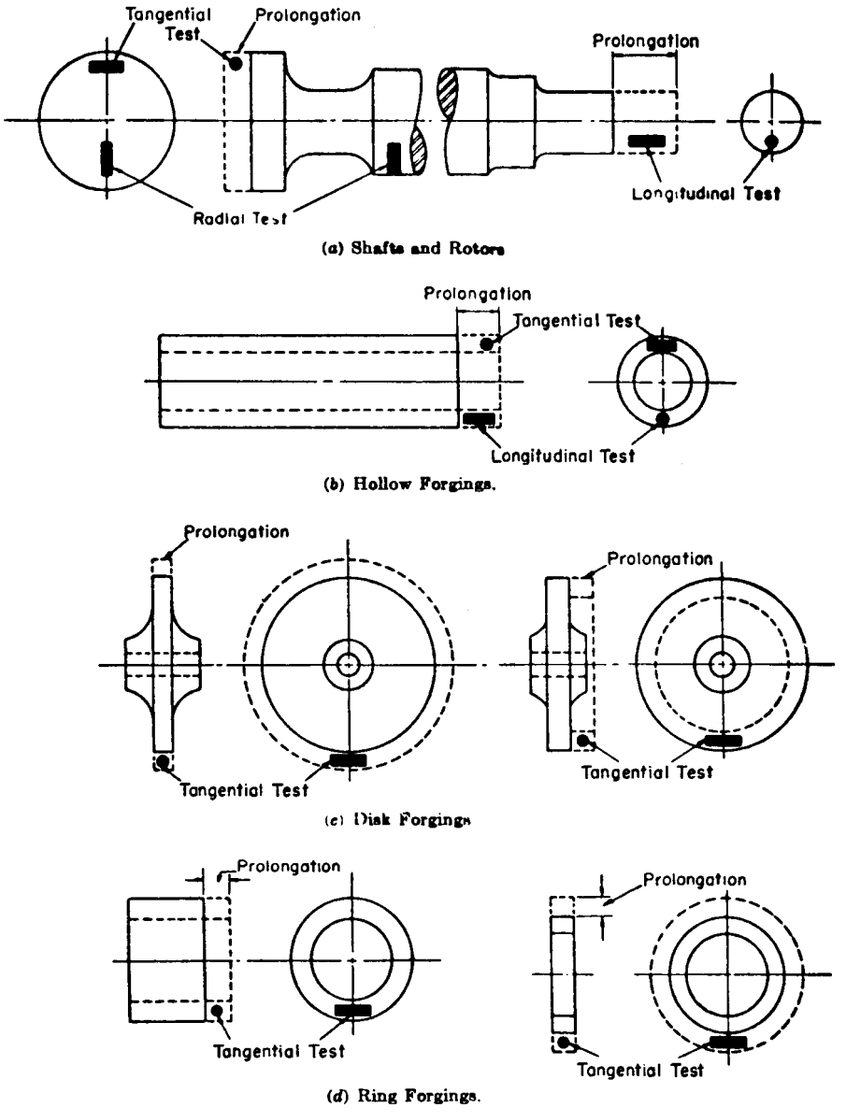
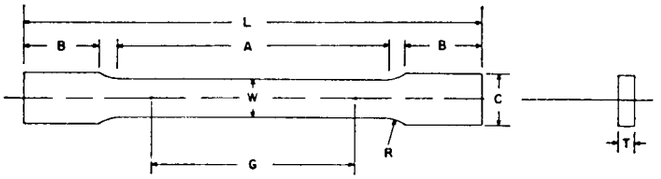


FIG.2 LOCATION OF TEST SPECIMENS FOR VARIOUS TYPES OF FORGINGS



DIMENSIONS

	Standard Specimens				Subsize Specimen	
	Plate-Type, 1½-in. Wide		Sheet-Type, ½-in. Wide		¼-in. Wide	
	in.	mm	in.	mm	in.	mm
G—Gage length (Notes 1 and 2)	8.00 ± 0.01	200 ± 0.25	2.000 ± 0.005	50.0 ± 0.10	1.000 ± 0.003	25.0 ± 0.08
W—Width (Notes 3, 4, and 5)	1½ + ⅛ − ¼	40 + 3 − 6	0.500 ± 0.010	12.5 ± 0.25	0.250 ± 0.002	6.25 ± 0.05
T—Thickness (Note 6)			thickness of material			
R—Radius of fillet, min	½	13	½	13	¼	6
L—Over-all length, min (Notes 2 and 7)	18	450	8	200	4	100
A—Length of reduced section, min	9	225	2¼	60	1¼	32
B—Length of grip section, min (Note 8)	3	75	2	50	1¼	32
C—Width of grip section, approximate (Notes 4, 9, and 10)	2	50	¾	20	⅜	10

NOTE 1—For the 1½-in. (40-mm) wide specimen, punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the reduced section. Either a set of nine or more punch marks 1 in. (25 mm) apart, or one or more pairs of punch marks 8 in. (200 mm) apart may be used.

NOTE 2—For the ½-in. (12.5-mm) wide specimen, gage marks for measuring the elongation after fracture shall be made on the ½-inch (12.5-mm) face or on the edge of the specimen and within the reduced section. Either a set of three or more marks 1.0 in. (25 mm) apart or one or more pairs of marks 2 in. (50 mm) apart may be used.

NOTE 3—For the three sizes of specimens, the ends of the reduced section shall not differ in width by more than 0.004, 0.002 or 0.001 in. (0.10, 0.05 or 0.025 mm), respectively. Also, there may be a gradual decrease in width from the ends to the center, but the width at either end shall not be more than 0.015 in., 0.005 in., or 0.003 in. (0.40, 0.10 or 0.08 mm), respectively, larger than the width at the center.

NOTE 4—For each of the three sizes of specimens, narrower widths (*W* and *C*) may be used when necessary. In such cases the width of the reduced section should be as large as the width of the material being tested permits; however, unless stated specifically, the requirements for elongation in a product specification shall not apply when these narrower specimens are used. If the width of the material is less than *W*, the sides may be parallel throughout the length of the specimen.

NOTE 5—The specimen may be modified by making the sides parallel throughout the length of the specimen, the width and toler‹ ›s being the same as those specified above. When necessary a narrower specimen may be used, in which case the width should be as great as the width of the material being tested permits. If the width is 1½ in. (38 mm) or less, the sides may be parallel throughout the length of the specimen.

NOTE 6—The dimension *T* is the thickness of the test specimen as provided for in the applicable material specifications. Minimum nominal thickness of 1½-in. (40-mm) wide specimens shall be 3/16 in. (5 mm), except as permitted by the product specification. Maximum nominal thickness of ½-in. (12.5-mm) and ¼-in. (6-mm) wide specimens shall be ¾ in. (19 mm) and ¼ in. (6 mm), respectively.

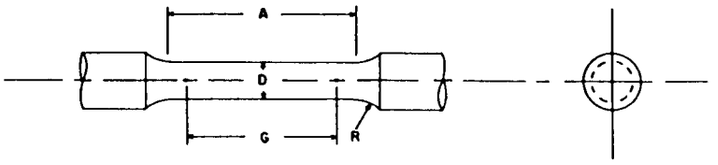
NOTE 7—To aid in obtaining axial loading during testing of ¼-in. (6-mm) wide specimens, the over-all length should be as the material will permit.

NOTE 8—It is desirable, if possible, to make the length of the grip section large enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips. If the thickness of ½-in. (13-mm) wide specimens is over ⅜ in. (10 mm), longer grips and correspondingly longer grip sections of the specimen may be necessary to prevent failure in the grip section.

NOTE 9—For standard sheet-type specimens and subsize specimens the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.01 and 0.005 in. (0.25 and 0.13 mm), respectively. However, for steel if the ends of the ½-in. (12.5-mm) wide specimen are symmetrical within 0.05 in. (1.0 mm) a specimen may be considered satisfactory for all but referee testing.

NOTE 10—For standard plate-type specimens the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.25 in. (6.35 mm) except for referee testing in which case the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in. (2.5 mm).

FIG. 3 RECTANGULAR TENSION TEST SPECIMENS



DIMENSIONS

Nominal Diameter	Standard Specimen		Small-Size Specimens Proportional to Standard							
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
	0.500	12.5	0.350	8.75	0.250	6.25	0.160	4.00	0.113	2.50
G—Gage length	2.00 ± 0.005	50.0 ± 0.10	1.400 ± 0.005	35.0 ± 0.10	1.000 ± 0.005	25.0 ± 0.10	0.640 ± 0.005	16.0 ± 0.10	0.450 ± 0.005	10.0 ± 0.10
D—Diameter (Note 1)	0.500 ± 0.010	12.5± 0.25	0.350 ± 0.007	8.75 ± 0.18	0.250 ± 0.005	6.25 ± 0.12	0.160 ± 0.003	4.00 ± 0.08	0.113 ± 0.002	2.50 ± 0.05
R—Radius of fillet, min	3/8	10	1/4	6	3/16	5	5/32	4	3/32	2
A—Length of reduced section, min (Note 2)	2 1/4	60	1 3/4	45	1 1/4	32	3/4	20	5/8	16

NOTE 1—The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1 percent larger in diameter than the center (controlling dimension).

NOTE 2—If desired, the length of the reduced section may be increased to accommodate an extensometer of any convenient gage length. Reference marks for the measurement of elongation should, nevertheless, be spaced at the indicated gage length.

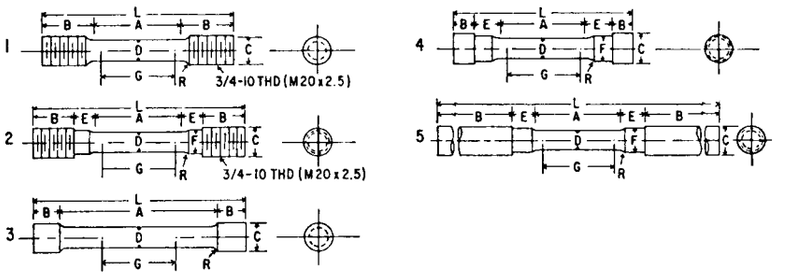
NOTE 3—The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial (see Fig. 9). If the ends are to be held in wedge grips it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

NOTE 4—On the round specimens in Figs. 5 and 6, the gage lengths are equal to four times the nominal diameter. In some product specifications other specimens may be provided for, but unless the 4-to-1 ratio is maintained within dimensional tolerances, the elongation values may not be comparable with those obtained from the standard test specimen.

NOTE 5—The use of specimens smaller than 0.250-in. (6.25-mm) diameter shall be restricted to cases when the material to be tested is of insufficient size to obtain larger specimens or when all parties agree to their use for acceptance testing. Smaller specimens require suitable equipment and greater skill in both machining and testing.

NOTE 6—Five sizes of specimens often used have diameters of approximately 0.505, 0.357, 0.252, 0.160, and 0.113 in., the reason being to permit easy calculations of stress from loads, since the corresponding cross sectional areas are equal or close to 0.200, 0.100, 0.0500, 0.0200, and 0.0100 $in.^2$, respectively. Thus, when the actual diameters agree with these values, the stresses (or strengths) may be computed using the simple multiplying factors 5, 10, 20 50, and 100, respectively. (The metric equivalents of these fixed diameters do not result in correspondingly convenient cross sectional area and multiplying factors.)

FIG. 4 STANDARD 0.500-IN. (12.5-MM) ROUND TENSION TEST SPECIMEN WITH 2-IN. (50-MM) GAGE LENGTH AND EXAMPLES OF SMALL-SIZE SPECIMENS PROPORTIONAL TO THE STANDARD SPECIMENS



DIMENSIONS

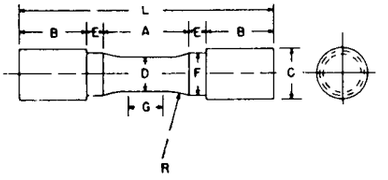
	Specimen 1		Specimen 2		Specimen 3		Specimen 4		Specimen 5	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
G—Gage length	2.000 ± 0.005	50.0 ± 0.10	2.000 ± 0.005	50.0 ± 0.10	2.000 ± 0.005	50.0 ± 0.10	2.000 ± 0.005	50.0 ± 0.10	2.00 ± 0.005	50.0 ± 0.10
D—Diameter (Note 1)	0.500 ± 0.010	12.5 ± 0.25	0.500 ± 0.010	12.5 ± 0.25	0.500 ± 0.010	12.5 ± 0.25	0.500 ± 0.010	12.5 ± 0.25	0.500 ± 0.010	12.5 ± 0.25
R—Radius of fillet, min	3/8	10	3/8	10	1/16	2	3/8	10	3/8	10
A—Length of reduced section	2 1/4, min	60, min	2 1/4, min	60, min	4, approximately	100, approximately	2 1/4, min	60, min	2 1/4, min	60, min
L—Over-all length, approximate	5	125	5 1/2	140	5 1/2	140	4 3/4	120	9 1/2	240
B—Grip section (Note 2)	1 3/8, approximately	35, approximately	1, approximately	25, approximately	3/4, approximately	20, approximately	1/2, approximately	13, approximately	3, min	75, min
C—Diameter of end section	3/4	20	3/4	20	23/32	18	7/8	22	3/4	20
E—Length of shoulder and fillet section, approximate	...	...	5/8	16	...	...	3/4	20	5/8	16
F—Diameter of shoulder	...	...	5/8	16	...	...	5/8	16	19/32	15

NOTE 1—The reduced section may have a gradual taper from the ends toward the center with the ends not more than 0.005 in. (0.10 mm) larger in diameter than the center.

NOTE 2—On Specimen 5 it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

NOTE 3—The types of ends shown are applicable for the standard 0.500-in. round tension test specimen; similar types can be used for subsize specimens. The use of UNF series of threads (3/4 by 16, 1/2 by 20, 3/8 by 24, and 1/4 by 28) is suggested for high-strength brittle materials to avoid fracture in the thread portion.

FIG. 5 SUGGESTED TYPES OF ENDS FOR STANDARD ROUND TENSION TEST SPECIMENS



DIMENSIONS

	Specimen 1		Specimen 2		Specimen 3	
	in.	mm	in.	mm	in.	mm
G—Length of parallel	Shall be equal to or greater than diameter *D*					
D—Diameter	0.500 ± 0.010	12.5 ± 0.25	0.750 ± 0.015	20.0 ± 0.40	1.25 ± 0.025	30.0 ± 0.60
R—Radius of fillet, min	1	25	1	25	2	50
A—Length of reduced section, min	1 1/4	32	1 1/2	38	2 1/4	60
L—Over-all length, min	3 3/4	95	4	100	6 3/8	160
B—Grip section, approximate	1	25	1	25	1 3/4	45
C—Diameter of end section, approximate	3/4	20	1 1/8	30	1 7/8	48
E—Length of shoulder, min	1/4	6	1/4	6	5/16	8
F—Diameter of shoulder	5/8 ± 1/64	16.0 ± 0.40	15/16 ± 1/64	24.0 ± 0.40	1 7/16 ± 1/64	36.5 ± 0.40

NOTE—The reduced section and shoulders (dimensions *A*, *D*, *E*, *F*, *G*, and *R*) shall be shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. Commonly the ends are threaded and have the dimensions *B* and *C* given above.

FIG. 6 STANDARD TENSION TEST SPECIMENS FOR CAST IRON

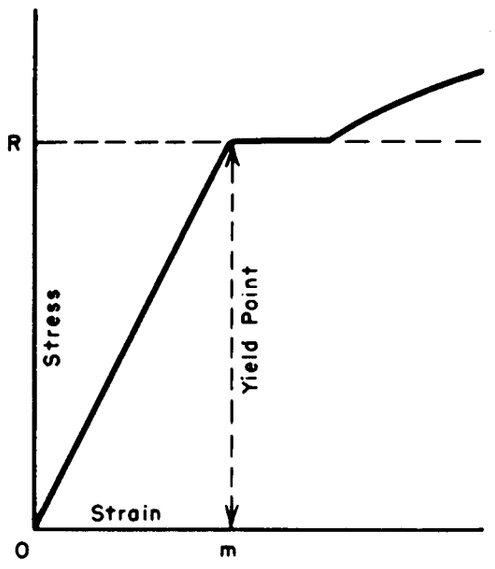


FIG. 7 STRESS-STRAIN DIAGRAM SHOWING YIELD POINT CORRESPONDING WITH TOP OF KNEE

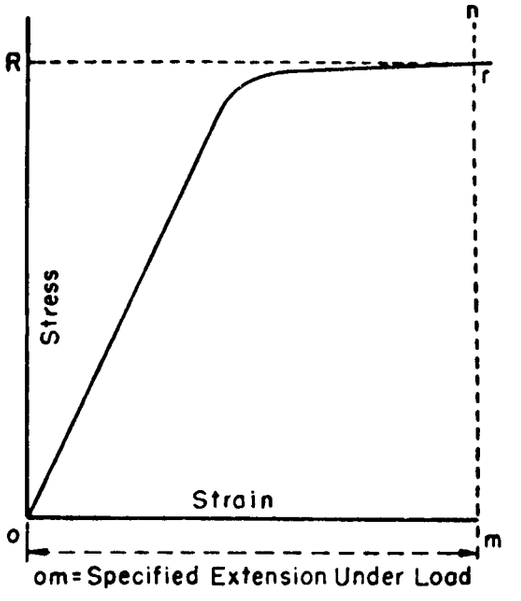


FIG. 8 STRESS-STRAIN DIAGRAM SHOWING YIELD POINT OR YIELD STRENGTH BY EXTENSION UNDER LOAD METHOD

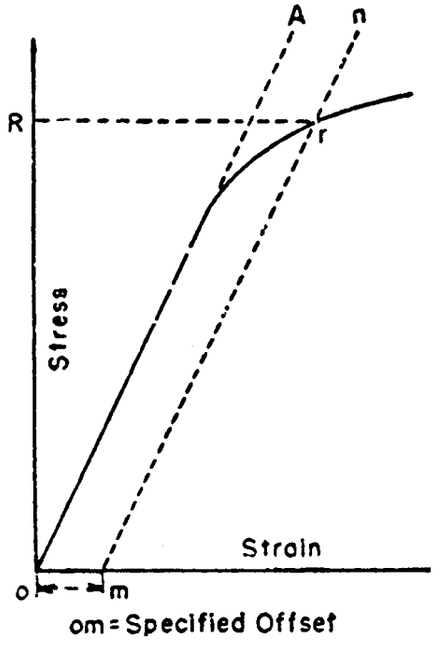
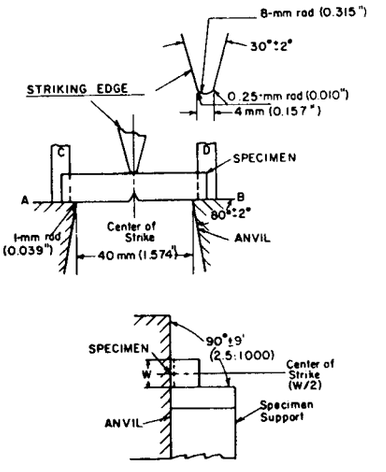


FIG. 9 STRESS-STRAIN DIAGRAM FOR DETERMINATION OF YIELD STRENGTH BY THE OFFSET METHOD



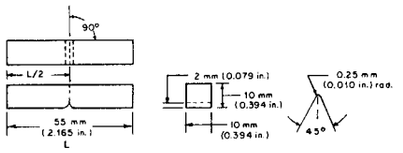
All dimensional tolerances shall be ±0.05 mm (0.002 in.) unless otherwise specified.

NOTE 1—A shall be parallel to B within 2:1000 and coplanar with B within 0.05 mm (0.002 in.).

NOTE 2—C shall be parallel to D within 20:1000 and coplanar with D within 0.125 mm (0.005 in.).

NOTE 3—Finish on unmarked parts shall be 4 μm (125 μin.).

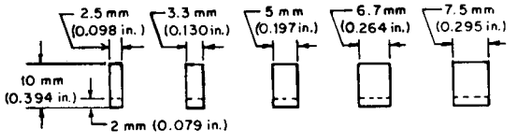
FIG. 10 CHARPY (SIMPLE BEAM) IMPACT TEST



NOTE—Permissible variations shall be as follows:

Adjacent sides shall be at	90° ± 10 min
Cross section dimensions	±0.025 mm (0.001 in.)
Length of specimen	+0, −2.5 mm (0.100 in.)
Angle of notch	±1°
Radius of notch	±0.025 mm (0.001 in.)
Dimensions to bottom of notch:	8 ± 0.025 mm (0.315 ± 0.001 in.)
Finish	63 μin. (1.6 μm) max on notched surface and opposite face; 125 μin. (3.2 μm) max on other two surfaces

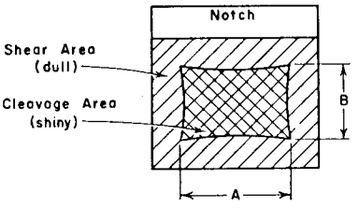
(a) Standard Specimens



NOTE—On subsize specimens, all dimensions and tolerances of the standard specimen remain constant with the exception of the width, which varies as shown above.

(b) Subsize Specimens

FIG. 11 CHARPY (SIMPLE-BEAM) IMPACT TEST SPECIMENS



NOTE 1—Measure average dimensions *A* and *B* to the nearest 0.02 in. or 0.5 mm.

NOTE 2—Determine the percent shear fracture using Table 4 or Table 5.

FIG. 12 DETERMINATION OF PERCENT SHEAR FRACTURE

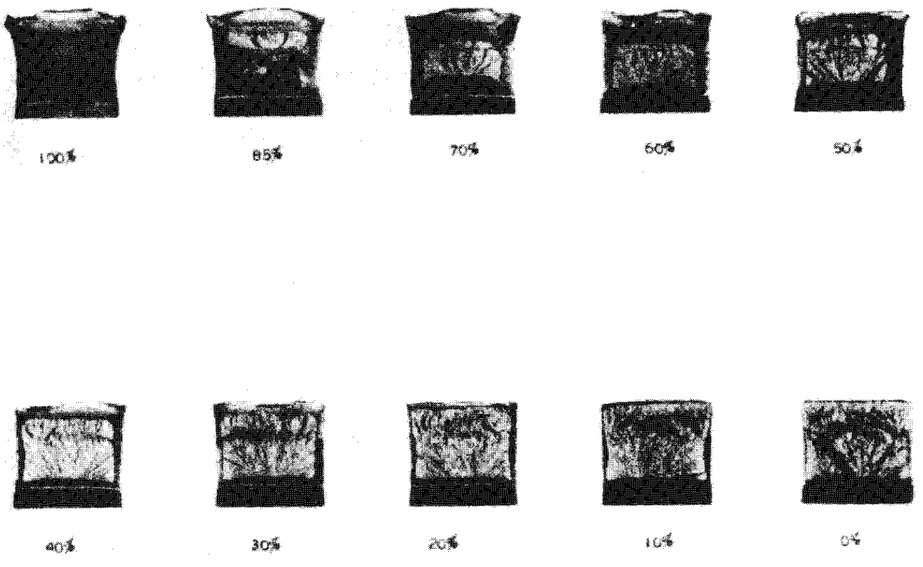


FIG. 13 FRACTURE APPEARANCE CHARTS AND PERCENT SHEAR FRACTURE COMPARATOR

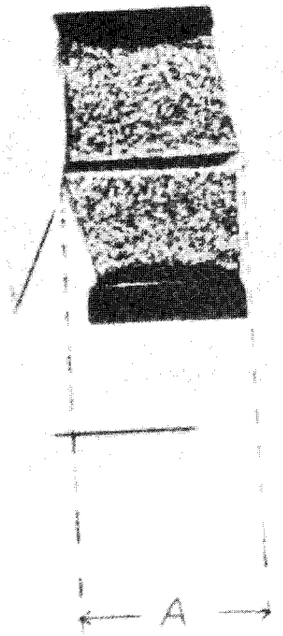


FIG. 14 HALVES OF BROKEN CHARPY V-NOTCH IMPACT SPECIMEN JOINED FOR THE MEASUREMENT OF LATERAL EXPANSION, DIMENSION *A*

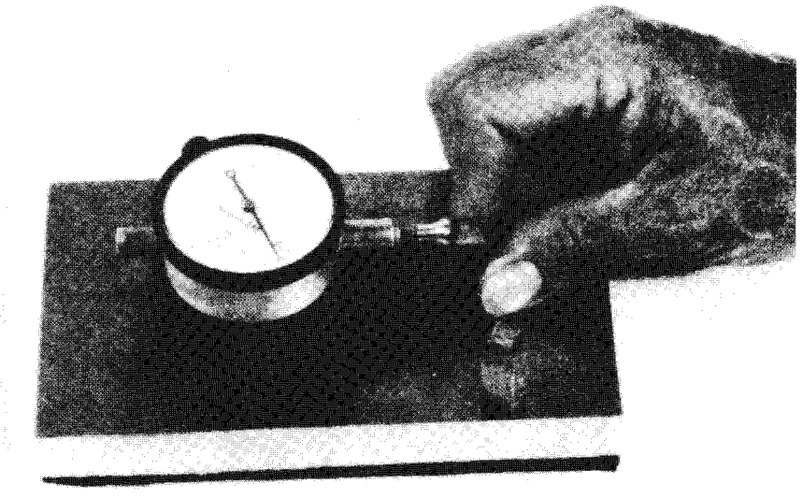


FIG. 15 LATERAL EXPANSION GAGE FOR CHARPY IMPACT SPECIMENS

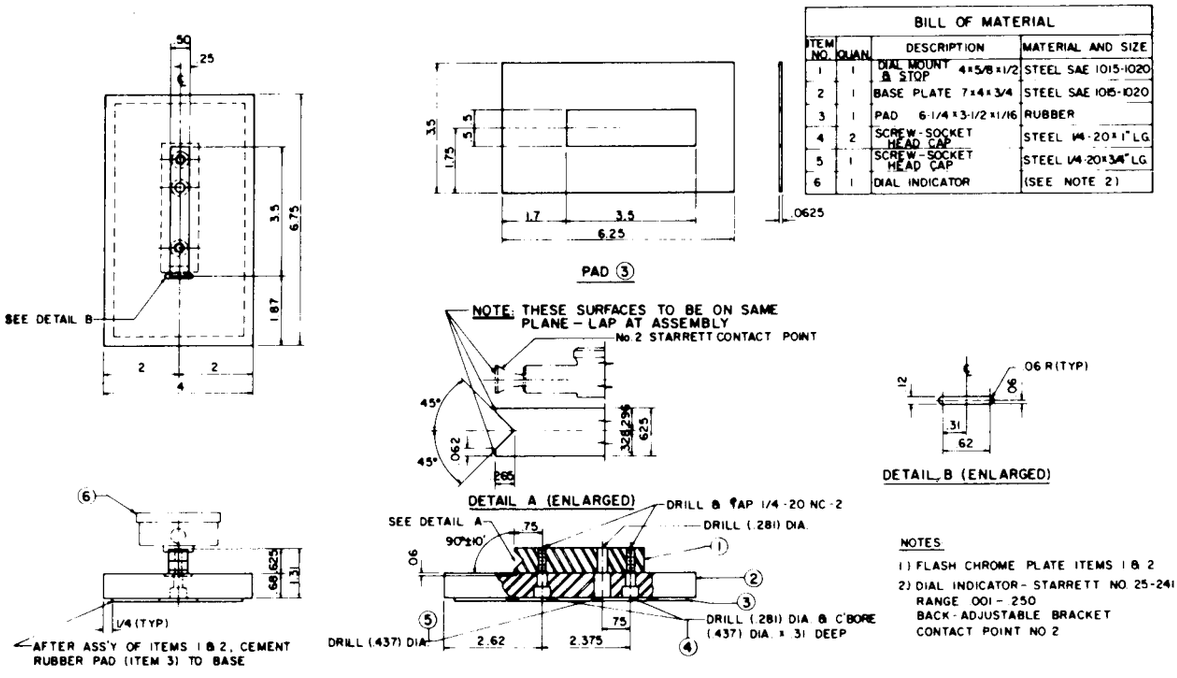


FIG. 16 ASSEMBLY AND DETAILS FOR LATERAL EXPANSION GAGE

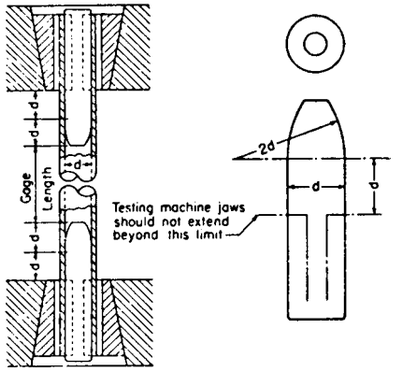
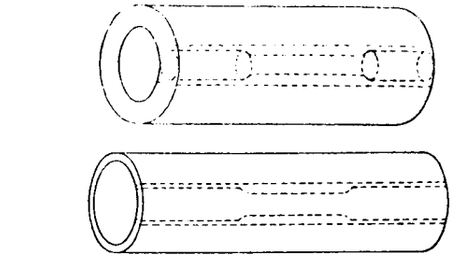
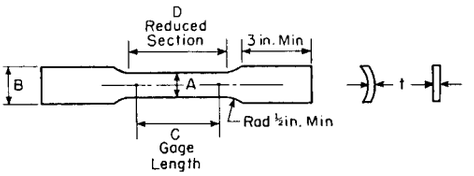


FIG. 17 METAL PLUGS FOR TESTING TUBULAR SPECIMENS, PROPER LOCATION OF PLUGS IN SPECIMEN AND OF SPECIMEN IN HEADS OF TESTING MACHINE



NOTE—The edges of the blank for the specimen shall be cut parallel to each other.

FIG. 18 LOCATION OF STRIP TENSION TEST SPECIMENS IN LARGE DIAMETER TUBING



DIMENSIONS

Specimen No.	Dimensions, in.			
	A	*B*	*C*	*D*
1	½ ± 0.015	1 1/16 approximately	2 ± 0.005	2¼ min
2	¾ ± 0.031	1 approximately	2 ± 0.005	2¼ min
			4 ± 0.005	4½ min
3	1 ± 0.062	1½ approximately	2 ± 0.005	2¼ min
			4 ± 0.005	4½ min
4	1½ ± ⅛	2 approximately	2 ± 0.010	2¼ min
			4 ± 0.015	4½ min
			8 ± 0.020	9 min

NOTE 1—Cross-sectional area may be calculated by multiplying *A* and *t*.
NOTE 2—The dimension *t* is the thickness of the test specimen as provided for in the applicable material specifications.
NOTE 3—The reduced section shall be parallel within 0.010 in. and may have a gradual taper in width from the ends toward the center, with the ends not more than 0.010 in. wider than the center.
NOTE 4—The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in.
NOTE 5—Metric equivalent: 1 in. = 25.4 mm.
NOTE 6—Specimens with sides parallel throughout their length are permitted, except for referee testing, provided: (*a*) the above tolerances are used; (*b*) an adequate number of marks are provided for determination of elongation; and (*c*) when yield strength is determined, a suitable extensometer is used. If the fracture occurs at a distance of less than 2*W* from the edge of the gripping device, the tensile properties determined may not be representative of the material. If the properties meet the minimum requirements specified, no further testing is required, but if they are less than the minimum requirements, discard the test and retest.

FIG. 19 DIMENSIONS AND TOLERANCES FOR STRIP TENSION TEST SPECIMENS FOR LARGE DIAMETER TUBING

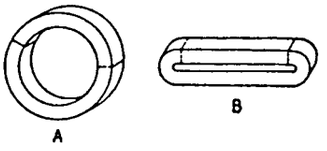
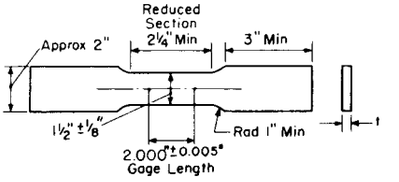


FIG. 20 LOCATION OF TRANSVERSE TENSION TEST SPECIMENS IN RING CUT FROM TUBULAR PRODUCTS



NOTE 1—The dimension *t* is the thickness of the test specimen as provided for in the applicable material specifications.
NOTE 2—The reduced section shall be parallel within 0.010 in. and may have a gradual taper in width from the ends toward the center, with the ends not more than 0.010 in. wider than the center.
NOTE 3—The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in.
NOTE 4—Metric equivalent: 1 in. = 25.4 mm.

FIG. 21 TRANSVERSE TENSION TEST SPECIMEN MACHINED FROM RING CUT FROM TUBULAR PRODUCTS

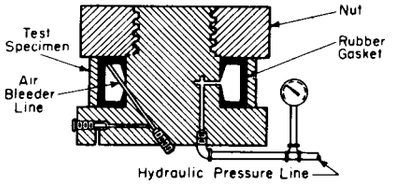


FIG. 22 TESTING MACHINE FOR DETERMINATION OF TRANSVERSE YIELD STRENGTH FROM ANNULAR RING SPECIMENS

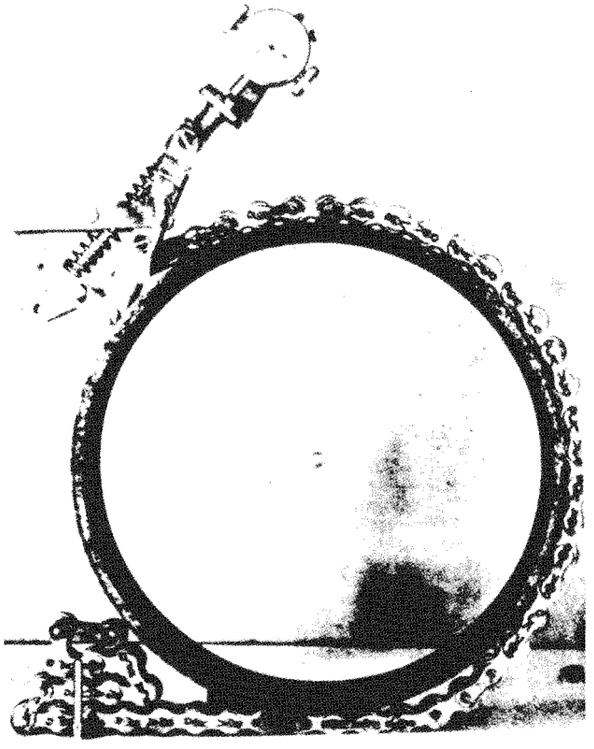


FIG. 23 ROLLER CHAIN TYPE EXTENSOMETER, UNCLAMPED

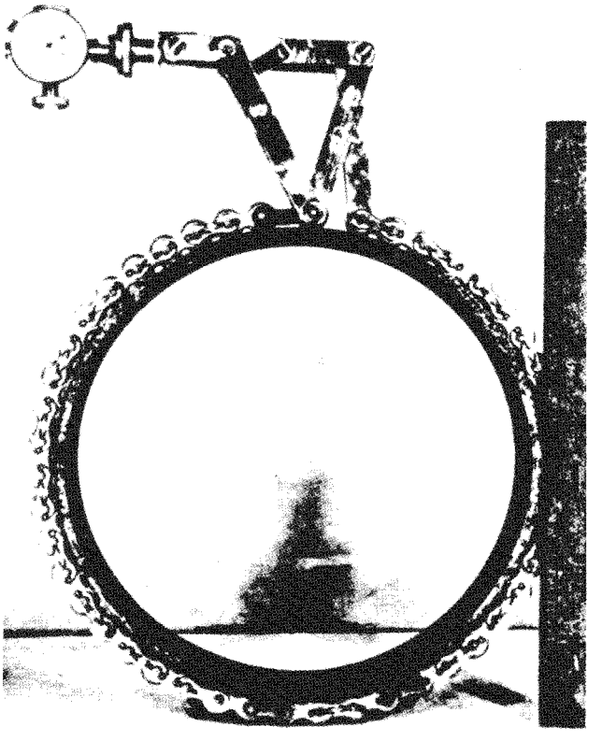


FIG. 24 ROLLER CHAIN TYPE EXTENSOMETER, CLAMPED

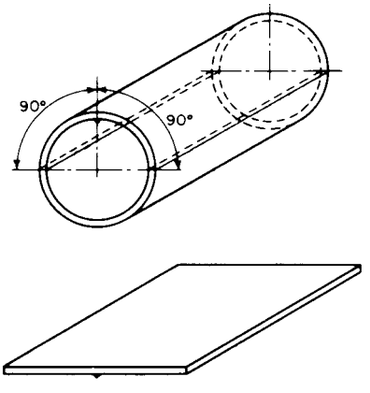


FIG. 25 REVERSE FLATTENING TEST

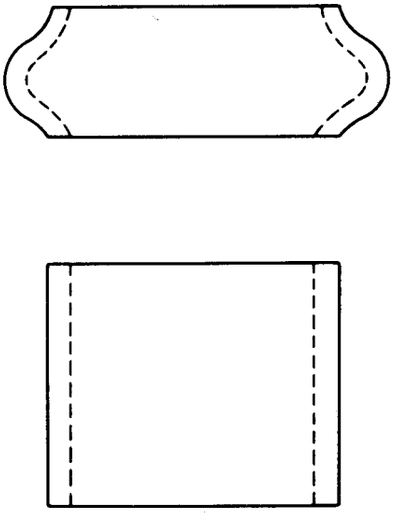
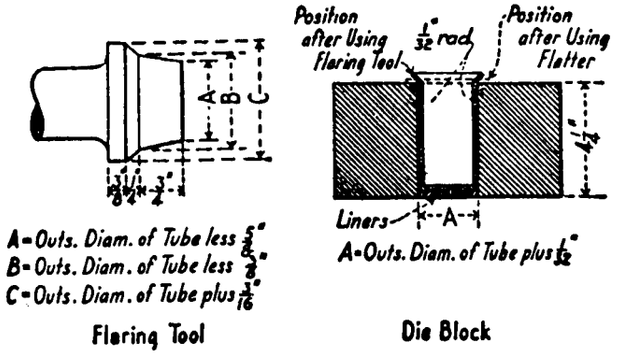


FIG. 26 CRUSH TEST SPECIMEN



NOTE—Metric equivalent: 1 in. = 25.4 mm.

FIG. 27 FLARING TOOL AND DIE BLOCK FOR FLANGE TEST

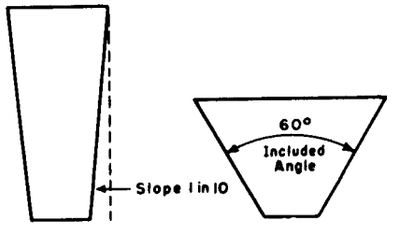
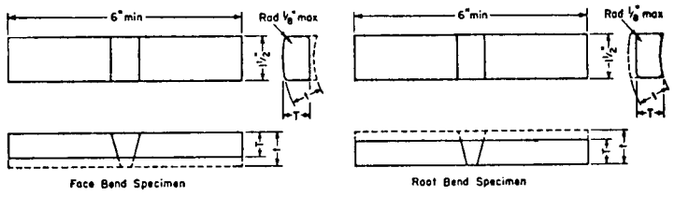


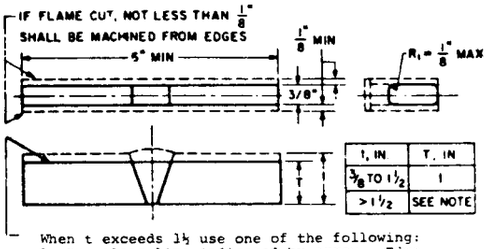
FIG. 28 TAPERED MANDRELS FOR FLARING TEST



NOTE—Metric equivalent: 1 in. = 25.4 mm.

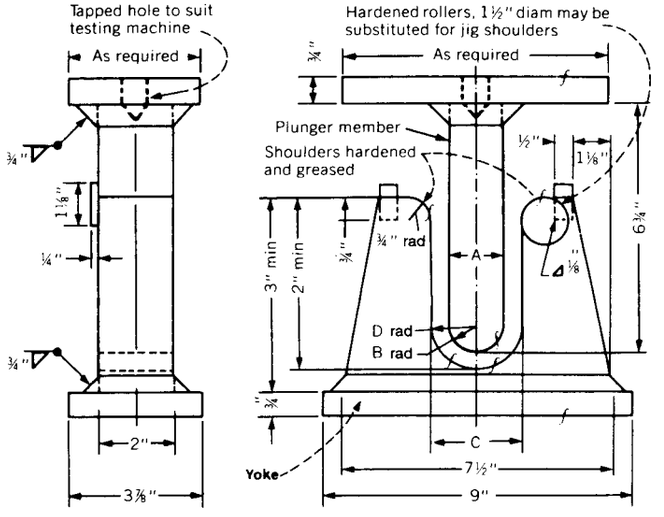
Pipe Wall Thickness (t), in.	Test Specimen Thickness, in.
Up to 3/8, incl	t
Over 3/8	3/8

FIG. 29(a) TRANSVERSE FACE- AND ROOT-BEND TEST SPECIMENS



NOTE—Metric equivalent: 1 in. = 25.4 mm.

FIG. 29(b) SIDE-BEND SPECIMEN FOR FERROUS MATERIALS



NOTE: Metric equivalent: 1 in. = 25.4 mm.

Test Specimen Thickness, in.	A	B	C	D	
3/8	1 1/2	3/4	2 3/8	1 3/16	
t	4*t*	2*t*	6*t* + 1/8	3*t* + 1/16	
					Material
3/8	2 1/2	1 1/4	3 3/8	1 11/16	Materials with a specified minimum tensile strength of 95 ksi or greater.
t	6 2/3*t*	3 1/3*t*	8 2/3*t* + 1/8	4 1/2*t* + 1/16	

FIG. 30 GUIDED-BEND TEST JIG

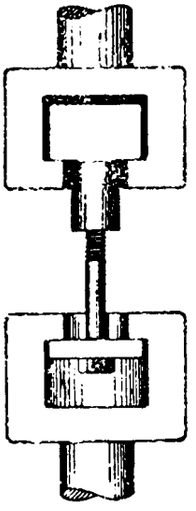
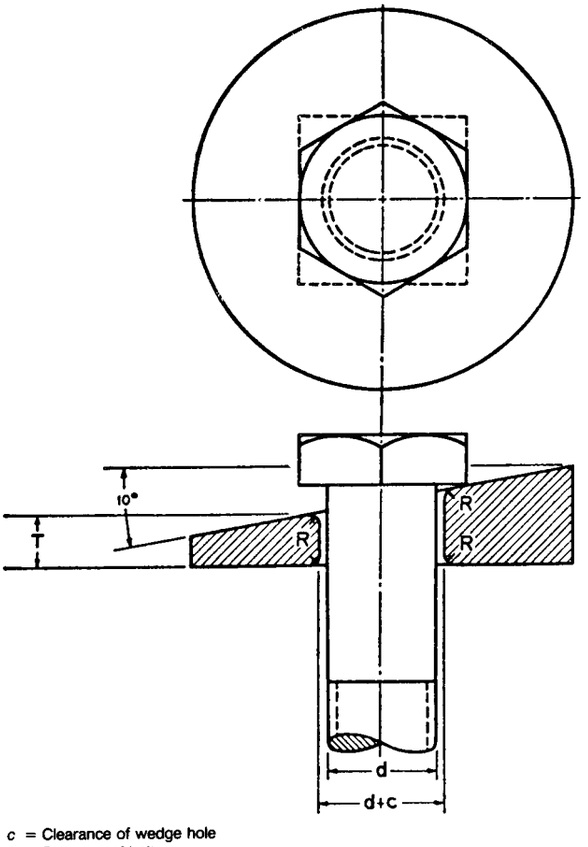
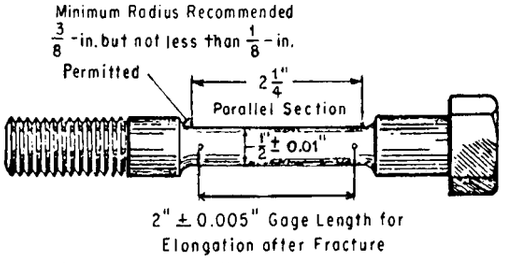


FIG. 31 TENSION TESTING FULL-SIZE BOLT



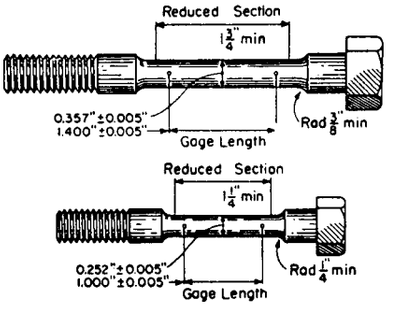
c = Clearance of wedge hole
d = Diameter of bolt
R = Radius
T = Thickness of wedge at short side of hole equal to one-half diameter of bolt

FIG. 32 WEDGE TEST DETAIL



NOTE—Metric equivalent: 1 in. = 25.4 mm.

FIG. 33 TENSION TEST SPECIMEN FOR BOLT WITH TURNED-DOWN SHANK



NOTE—Metric equivalent: 1 in. = 25.4 mm.

FIG. 34 EXAMPLES OF SMALL SIZE SPECIMENS PROPORTIONAL TO STANDARD 2-IN. GAGE LENGTH SPECIMEN

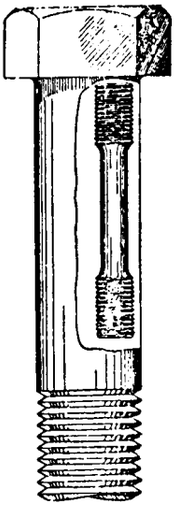


FIG. 35 LOCATION OF STANDARD ROUND 2-IN. GAGE LENGTH TENSION TEST SPECIMEN WHEN TURNED FROM LARGE SIZE BOLT

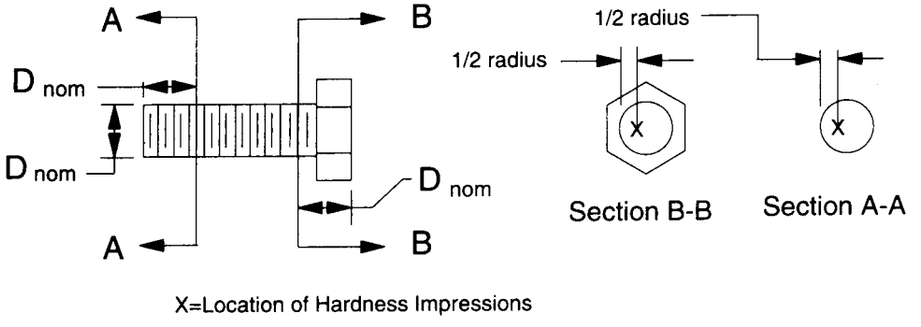


FIG. 36 HARDNESS TEST LOCATIONS FOR BOLTS IN A DISPUTE

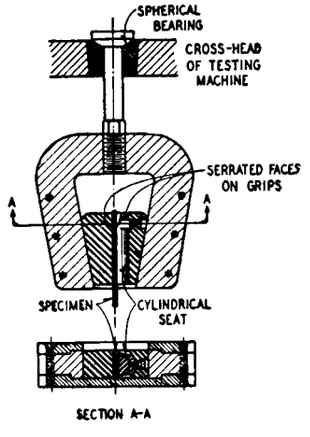


FIG. 37 WEDGE-TYPE GRIPPING DEVICE

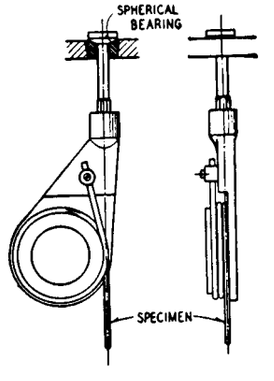


FIG. 38 SNUBBING-TYPE GRIPPING DEVICE

ANNEXES

(Mandatory Information)

A1. STEEL BAR PRODUCTS

A1.1 Scope

A1.1.1 This supplement delineates only those details which are peculiar to hot-rolled and cold-finished steel bars and are not covered in the general section of these test methods.

A1.2 Orientation of Test Specimens

A1.2.1 Carbon and alloy steel bars and bar-size shapes, due to their relatively small cross-sectional dimensions, are customarily tested in the longitudinal direction. In special cases where size permits and the fabrication or service of a part justifies testing in a transverse direction, the selection and location of test or tests are a matter of agreement between the manufacturer and the purchaser.

A1.3 Tension Test

A1.3.1 *Carbon Steel Bars* — Carbon steel bars are not commonly specified to tensile requirements in the as-rolled condition for sizes of rounds, squares, hexagons, and octagons under ½ in. (13 mm) in diameter or distance between parallel faces nor for other bar-size sections, other than flats, less than 1 in.^{2} (645 mm^2) in cross-sectional area.

A1.3.2 *Alloy Steel Bars* — Alloy steel bars are usually not tested in the as-rolled condition.

A1.3.3 When tension tests are specified, the practice for selecting test specimens for hot-rolled and cold-finished steel bars of various sizes shall be in accordance with Table A1.1, unless otherwise specified in the product specification.

A1.4 Bend Test

A1.4.1 When bend tests are specified, the recommended practice for hot-rolled and cold-finished steel bars shall be in accordance with Table A1.2.

A1.5 Hardness Test

A1.5.1 *Hardness Tests on Bar Products* — flats, rounds, squares, hexagons and octagons-is conducted on the surface after a minimum removal of 0.015 in. to provide for accurate hardness penetration.

A2. STEEL TUBULAR PRODUCTS

A2.1 Scope

A2.1.1 This supplement covers definitions and methods of testing peculiar to tubular products which are not covered in the general section of these methods.

A2.1.2 Tubular shapes covered by this specification shall not be limited to products with circular cross sections but include shapes such as rectangular structural tubing.

A2.2 Tension Test

A2.2.1 *Full-Size Longitudinal Test Specimens:*

A2.2.1.1 It is standard practice to use tension test specimens of full-size tubular sections within the limit of the testing equipment. Snug-fitting metal plugs should be inserted far enough in the end of such tubular specimens to permit the testing machine jaws to grip the specimens properly without crushing. A design that may be used for such plugs is shown in Fig. A2.1. The plugs shall not extend into that part of the specimen on which the elongation is measured (Fig. A2.1). Care should be exercised to see that insofar as practicable, the load in such cases is applied axially. The length of the full-section specimen depends on the gage length prescribed for measuring the elongation.

A2.2.1.2 Unless otherwise required by the individual product specification, the gage length for furnace-welded pipe is normally 8 in. (200 mm), except that for nominal sizes ¾ in. and smaller, the gage length shall be as follows:

Nominal Size, in.	Gage Length, in. (mm)
¾ and ½	6 (150)
⅜ and ¼	4 (100)
⅛	2 (50)

A2.2.1.3 For seamless and electric-welded pipe and tubes the gage length is 2 in. However, for tubing having an outside diameter of ⅜ in. (10 mm) or less, it is customary to use a gage length equal to four times the outside diameter when elongation values comparable to larger specimens are required.

A2.2.1.4 To determine the cross-sectional area of the full-section specimen, measurements shall be recorded as the average or mean between the greatest and least measurements of the outside diameter and the average or mean wall thickness, to the nearest 0.001 in. (0.025 mm) and the cross-sectional area is determined by the following equation:

$$A = 3.1416t\ (D - t)$$

where:

A = sectional area, in.^{2}
D = outside diameter, in., and
t = thickness of tube wall, in.

NOTE A2.1 — There exist other methods of cross-sectional area determination, such as by weighing of the specimens, which are equally accurate or appropriate for the purpose.

A2.2.2 *Longitudinal Strip Test Specimens:*

A2.2.2.1 For larger sizes of tubular products which cannot be tested in full-section, longitudinal test specimens are obtained from strips cut from the tube or pipe as indicated in Fig. A2.2 and machined to the dimensions shown in Fig. A2.3. For furnace-welded tubes or pipe the 8 in. gage length specimen as shown in Fig. A2.3 is standard, the specimen being located at approximately 90° from the weld. For seamless and electric-welded tubes or pipe, the 2 in. gage length specimen as shown in Fig. A2.3 (1) is standard, the specimen being located approximately 90° from the weld in the case of electric-welded tubes. Specimens of the type shown in Fig. A2.3 may be tested with grips having a surface contour corresponding to the curvature of the tubes. When grips with curved faces are not available, the ends of the specimens may be flattened without heating. Standard tension test specimens, as shown in specimen No. 4 of Fig. A2.3, are nominally 1½ in. (38 mm) wide in the gage length section. When sub-size specimens are necessary due to the dimensions and character of the material to be tested, specimens 1, 2, or 3 shown in Fig. A2.3 where applicable, are considered standard.

NOTE A2.2 — An exact formula for calculating the cross-sectional area of specimens of the type shown in Fig. A2.3 taken from a circular tube is given in Test Methods E8 or E8M.

A2.2.2.2 The width should be measured at each end of the gage length to determine parallelism and also at the center. The thickness should be measured at the center and used with the center measurement of the width to determine the cross-sectional area. The center width dimension should be recorded to the nearest 0.005 in. (0. 127 mm), and the thickness measurement to the nearest 0.001 in.

A2.2.3 *Transverse Strip Test Specimens:*

A2.2.3.1 In general, transverse tension tests are not recommended for tubular products, in sizes smaller than 8 in. in nominal diameter. When required, transverse tension test specimens may be taken from rings cut from ends of tubes or pipe as shown in Fig. A2.4. Flattening of the specimen may be done either after separating it from the tube as in Fig. A2.4 *(a)* or before separating it as in Fig. A2.4 *(b)* and may be done hot or cold; but if the flattening is done cold, the specimen may subsequently be normalized. Specimens from tubes or pipe for which heat treatment is specified, after being flattened either hot or cold, shall be given the same treatment as the tubes or pipe. For tubes or pipe having a wall thickness of less than ¾ in. (19 mm), the transverse test specimen shall be of the form and dimensions shown in Fig. A2.5 and either or both surfaces may be machined to secure uniform thickness. Specimens for transverse tension tests on welded steel tubes or pipe to determine strength of welds, shall be located perpendicular to the welded seams with the weld at about the middle of their length.

A2.2.3.2 The width should be measured at each end of the gage length to determine parallelism and also at the center. The thickness should be measured at the center and used with the center measurement of the width to determine the cross-sectional area. The center width dimension should be recorded to the nearest 0.005 in. (0.127 mm), and the thickness measurement to the nearest 0.001 in. (0.025 mm).

A2.2.4 *Round Test Specimens:*

A2.2.4.1 When provided for in the product specification, the round test specimen shown in Fig. 4 may be used.

A2.2.4.2 The diameter of the round test specimen is measured at the center of the specimen to the nearest 0.001 in. (0.025 mm).

A2.2.4.3 Small-size specimens proportional to standard, as shown in Fig. 4, may be used when it is necessary to test material from which the standard specimen cannot be prepared. Other sizes of small-size specimens may be used. In any such small-size specimen, it is important that the gage length for measurement of elongation be four times the diameter of the specimen (see Note 4, Fig. 4). The elongation requirements for

the round specimen 2 in. gage length in the product specification shall apply to the small-size specimens.

A2.2.4.4 For transverse specimens, the section from which the specimen is taken shall not be flattened or otherwise deformed.

A2.3 Determination of Transverse Yield Strength, Hydraulic Ring-Expansion Method

A2.3.1 Hardness tests are made on the outside surface, inside surface, or wall cross-section depending upon product-specification limitation. Surface preparation may be necessary to obtain accurate hardness values.

A2.3.2 A testing machine and method for determining the transverse yield strength from an annular ring specimen, have been developed and described in A2.3.3 through A2.3.5.

A2.3.3 A diagrammatic vertical cross-sectional sketch of the testing machine is shown in Fig. A2.6.

A2.3.4 In determining the transverse yield strength on this machine, a short ring [commonly 3 in. (76 mm) in length] test specimen is used. After the large circular nut is removed from the machine, the wall thickness of the ring specimen is determined and the specimen is telescoped over the oil resistant rubber gasket. The nut is then replaced, but is not turned down tight against the specimen. A slight clearance is left between the nut and specimen for the purpose of permitting free radial movement of the specimen as it is being tested. Oil under pressure is then admitted to the interior of the rubber gasket through the pressure line under the control of a suitable valve. An accurately calibrated pressure gage serves to measure oil pressure. Any air in the system is removed through the bleeder line. As the oil pressure is increased, the rubber gasket expands which in turn stresses the specimen circumferentially. As the pressure builds up, the lips of the rubber gasket act as a seal to prevent oil leakage. With continued increase in pressure, the ring specimen is subjected to a tension stress and elongates accordingly. The entire outside circumference of the ring specimen is considered as the gage length and the strain is measured with a suitable extensometer which will be described later. When the desired total strain or extension under load is reached on the extensometer, the oil pressure in pounds per square inch is read and by employing Barlow's formula, the unit yield strength is calculated. The yield strength, thus determined, is a true result since the test specimen has not been cold worked by flattening and closely approximates the same condition as the tubular section from which it is cut. Further, the test closely simulates service conditions in pipe lines. One testing machine unit may be used for several different sizes of pipe by the use of suitable rubber gaskets and adapters.

NOTE A2.3 — Barlow's formula may be stated two ways:

$$(1)\ P = 2St/D$$
$$(2)\ S = PD/2t$$

where:

P = internal hydrostatic pressure, psi,
S = unit circumferential stress in the wall of the tube produced by the internal hydrostatic pressure, psi,
t = thickness of the tube wall in., and
D = outside diameter of the tube, in.

A2.3.5 A roller chain type extensometer which has been found satisfactory for measuring the elongation of the ring specimen is shown in Figs. A2.7 and A2.8. Fig. A2.7 shows the extensometer in position, but unclamped, on a ring specimen. A small pin, through which the strain is transmitted to and measured by the dial gage, extends through the hollow threaded stud. When the extensometer is clamped, as shown in Fig. A2.8, the desired tension which is necessary to hold the instrument in place and to remove any slack, is exerted on the roller chain by the spring. Tension on the spring may be regulated as desired by the knurled thumb screw. By removing or adding rollers, the roller chain may be adapted for different sizes of tubular sections.

A2.4 Hardness Tests

A2.4.1 Hardness tests are made either on the outside or the inside surfaces on the end of the tube as appropriate.

A2.4.2 The standard 3000 kgf Brinell load may cause too much deformation in a thin-walled tubular specimen. In this case the 500 kgf load shall be applied, or inside stiffening by means of an internal anvil should be used. Brinell testing shall not be applicable to tubular products less than 2 in. (51 mm) in outside diameter, or less than 0.200 in. (5.1 mm) in wall thickness.

A2.4.3 The Rockwell hardness tests are normally made on the inside surface, a flat on the outside surface, or on the wall cross-section depending upon the product limitation. Rockwell hardness tests are not performed on tubes smaller than $^{5}/_{16}$ in. (7.9 mm) in outside diameter, nor are they performed on the inside surface of tubes with less than $^{1}/_{4}$ in. (6.4 mm) inside diameter.

Rockwell hardness tests are not performed on annealed tubes with walls less than 0.065 in. (1.65 mm) thick or cold worked or heat treated tubes with walls less than 0.049 in. (1.24 mm) thick. For tubes with wall thicknesses less than those permitting the regular Rockwell hardness test, the Superficial Rockwell test is sometimes substituted. Transverse Rockwell hardness readings can be made on tubes with a wall thickness of 0.187 in. (4.75 mm) or greater. The curvature and the wall thickness of the specimen impose limitations on the Rockwell hardness test. When a comparison is made between Rockwell determinations made on the outside surface and determinations made on the inside surface, adjustment of the readings will be required to compensate for the effect of curvature. The Rockwell B scale is used on all materials having an expected hardness range of B 0 to B 100. The Rockwell C scale is used on material having an expected hardness range of C 20 to C 68.

A2.4.4 Superficial Rockwell hardness tests are normally performed on the outside surface whenever possible and whenever excessive spring back is not encountered. Otherwise, the tests may be performed on the inside. Superficial Rockwell hardness tests shall not be performed on tubes with an inside diameter of less than $\frac{1}{4}$ in. (6.4 mm). The wall thickness limitations for the Superficial Rockwell hardness test are given in Tables A2.1 and A2.2.

A2.4.5 When the outside diameter, inside diameter, or wall thickness precludes the obtaining of accurate hardness values, tubular products shall be specified to tensile properties and so tested.

A2.5 Manipulating Tests

A2.5.1 The following tests are made to prove ductility of certain tubular products:

A2.5.1.1 *Flattening Test* — The flattening test as commonly made on specimens cut from tubular products is conducted by subjecting rings from the tube or pipe to a prescribed degree of flattening between parallel plates (Fig. A2.4). The severity of the flattening test is measured by the distance between the parallel plates and is varied according to the dimensions of the tube or pipe. The flattening test specimen should not be less than $2\frac{1}{2}$ in. (63.5 mm) in length and should be flattened cold to the extent required by the applicable material specifications.

A2.5.1.2 *Reverse Flattening Test* — The reverse flattening test is designed primarily for application to electric-welded tubing for the detection of lack of penetration or overlaps resulting from flash removal in the weld. The specimen consists of a length of tubing approximately 4 in. (102 mm) long which is split longitudinally 90° on each side of the weld. The sample is then opened and flattened with the weld at the point of maximum bend (Fig. A2.9).

A2.5.1.3 *Crush Test* — The crush test, sometimes referred to as an upsetting test, is usually made on boiler and other pressure tubes, for evaluating ductility (Fig. A2.10). The specimen is a ring cut from the tube, usually about $2\frac{1}{2}$ in. (63.5 mm) long. It is placed on end and crushed endwise by hammer or press to the distance prescribed by the applicable material specifications.

A2.5.1.4 *Flange Test* — The flange test is intended to determine the ductility of boiler tubes and their ability to withstand the operation of bending into a tube sheet. The test is made on a ring cut from a tube, usually not less than 4 in. (100 mm) long and consists of having a flange turned over at right angles to the body of the tube to the width required by the applicable material specifications. The flaring tool and die block shown in Fig. A2.11 are recommended for use in making this test.

A2.5.1.5 *Flaring Test* — For certain types of pressure tubes, an alternate to the flange test is made. This test consists of driving a tapered mandrel having a slope of 1 in 10 as shown in Fig. A2.12 *(a)* or a 60° included angle as shown in Fig. A2.12 *(b)* into a section cut from the tube, approximately 4 in. (100 mm) in length, and thus expanding the specimen until the inside diameter has been increased to the extent required by the applicable material specifications.

A2.5.1.6 *Bend Test* — For pipe used for coiling in sizes 2 in. and under a bend test is made to determine its ductility and the soundness of weld. In this test a sufficient length of full-size pipe is bent cold through 90° around a cylindrical mandrel having a diameter 12 times the nominal diameter of the pipe. For close coiling, the pipe is bent cold through 180° around a mandrel having a diameter 8 times the nominal diameter of the pipe.

A2.5.1.7 *Transverse Guided Bend Test of Welds* — This bend test is used to determine the ductility of fusion welds. The specimens used are approximately $1\frac{1}{2}$ in. (38 mm) wide, at least 6 in. (152 mm) in length with the weld at the center, and are machined in accordance with Fig. A2.13(a) for face and root bend tests and in accordance with Fig. A2.13(b) for side bend tests. The dimensions of the plunger

shall be as shown in Fig. A2.14 and the other dimensions of the bending jig shall be substantially as given in this same figure. A test shall consist of a face bend specimen and a root bend specimen or two side bend specimens. A face bend test requires bending with the inside surface of the pipe against the plunger; a root bend test requires bending with the outside surface of the pipe against the plunger; and a side bend test requires bending so that one of the side surfaces becomes the convex surface of the bend specimen.

(a) Failure of the bend test depends upon the appearance of cracks in the area of the bend, of the nature and extent described in the product specifications.

A3. STEEL FASTENERS

A3.1 Scope

A3.1.1 This supplement covers definitions and methods of testing peculiar to steel fasteners which are not covered in the general section of Test Methods and Definitions A 370. Standard tests required by the individual product specifications are to be performed as outlined in the general section of these methods.

A3.1.2 These tests are set up to facilitate production control testing and acceptance testing with certain more precise tests to be used for arbitration in case of disagreement over test results.

A3.2 Tension Tests

A3.2.1 It is preferred that bolts be tested full size, and it is customary, when so testing bolts to specify a minimum ultimate load in pounds, rather than a minimum ultimate strength in pounds per square inch. Three times the bolt nominal diameter has been established as the minimum bolt length subject to the tests described in the remainder of this section. Sections A3.2.1.1 through A3.2.1.3 apply when testing bolts full size. Section A3.2.1.4 shall apply where the individual product specifications permit the use of machined specimens.

A3.2.1.1 *Proof Load* — Due to particular uses of certain classes of bolts it is desirable to be able to stress them, while in use, to a specified value without obtaining any permanent set. To be certain of obtaining this quality the proof load is specified. The proof load test consists of stressing the bolt with a specified load which the bolt must withstand without permanent set. An alternate test which determines yield strength of a full size bolt is also allowed. Either of the following Methods, 1 or 2, may be used but Method 1 shall be the arbitration method in case of any dispute as to acceptance of the bolts.

A3.2.1.2 *Proof Load Testing Long Bolts* — When full size tests are required, proof load Method 1 is to be limited in application to bolts whose length does not exceed 8 in. (203 mm) or 8 times the nominal diameter, whichever is greater. For bolts longer than 8 in. or 8 times the nominal diameter, whichever is greater, proof load Method 2 shall be used.

(a) Method 1, Length Measurement — The overall length of a straight bolt shall be measured at its true center line with an instrument capable of measuring changes in length of 0.0001 in. (0.0025 mm) with an accuracy of 0.0001 in. in any 0.001 in. (0.025 mm) range. The preferred method of measuring the length shall be between conical centers machined on the center line of the bolt, with mating centers on the measuring anvils. The head or body of the bolt shall be marked so that it can be placed in the same position for all measurements. The bolt shall be assembled in the testing equipment as outlined in A3.2.1.4, and the proof load specified in the product specification shall be applied. Upon release of this load the length of the bolt shall be again measured and shall show no permanent elongation. A tolerance of ± 0.0005 in. (0.0127 mm) shall be allowed between the measurement made before loading and that made after loading. Variables, such as straightness and thread alignment (plus measurement error), may result in apparent elongation of the fasteners when the proof load is initially applied. In such cases, the fastener may be retested using a 3 percent greater load, and may be considered satisfactory if the length after this loading is the same as before this loading (within the 0.0005 in. tolerance for measurement error).

A3.2.1.3 *Proof Load-Time of Loading* — The proof load is to be maintained for a period of 10 s before release of load, when using Method 1.

(a) Method 2, Yield Strength — The bolt shall be assembled in the testing equipment as outlined in A3.2.1.4. As the load is applied, the total elongation of the bolt or any part of the bolt which includes the exposed six threads shall be measured and recorded to produce a load-strain or a stress-strain diagram. The load or stress at an offset equal to 0.2 percent of the length of bolt occupied by 6 full threads shall be determined by the method described in 13.2.1 of these methods, A 370. This load or stress shall not be less than that prescribed in the product specification.

A3.2.1.4 *Axial Tension Testing of Full Size Bolts* — Bolts are to be tested in a holder with the load axially applied between the head and a nut or

suitable fixture (Fig. A3.1), either of which shall have sufficient thread engagement to develop the full strength of the bolt. The nut or fixture shall be assembled on the bolt leaving six complete bolt threads unengaged between the grips, except for heavy hexagon structural bolts which shall have four complete threads unengaged between the grips. To meet the requirements of this test there shall be a tensile failure in the body or threaded section with no failure at the junction of the body, and head. If it is necessary to record or report the tensile strength of bolts as psi values the stress area shall be calculated from the mean of the mean root and pitch diameters of Class 3 external threads as follows:

$$A_s = 0.7854[D - (0.9743/n)]^2$$

where:

A_s = stress area, in.^{2},
D = nominal diameter, in., and
n = number of threads per inch.

A3.2.1.5 *Tension Testing of Full-Size Bolts with a Wedge* — The purpose of this test is to obtain the tensile strength and demonstrate the "head quality" and ductility of a bolt with a standard head by subjecting it to eccentric loading. The ultimate load on the bolt shall be determined as described in A3.2.1.4, except that a 10° wedge shall be placed under the same bolt previously tested for the proof load (see A3.2.1.1). The bolt head shall be so placed that no corner of the hexagon or square takes a bearing load, that is, a flat of the head shall be aligned with the direction of uniform thickness of the wedge (Fig. A3.2). The wedge shall have an included angle of 10° between its faces and shall have a thickness of one-half of the nominal bolt diameter at the short side of the hole. The hole in the wedge shall have the following clearance over the nominal size of the bolt, and its edges, top and bottom, shall be rounded to the following radius:

Nominal Bolt Size, in.	Clearance in Hole, in. (mm)	Radius on Corners of Hole, in. (mm)
1/4 to 1/2	0.030 (0.76)	0.030 (0.76)
9/16 to 3/4	0.050 (1.3)	0.060 (1.5)
7/8 to 1	0.063 (1.5)	0.060 (1.5)
1 1/8 to 1 1/4	0.063 (1.5)	0.125 (3.2)
1 3/8 to 1 1/2	0.094 (2.4)	0.125 (3.2)

A3.2.1.6 *Wedge Testing of HT Bolts Threaded to Head* — For heat-treated bolts over 100,000 psi (690 MPa) minimum tensile strength and that are threaded 1 diameter and closer to the underside of the head, the wedge angle shall be 6° for sizes 1/4 through 3/4 in. (6.35 to 19.0 mm) and 4° for sizes over 3/4 in.

A3.2.1.7 *Tension Testing of Bolts Machined to Round Test Specimens:*

(a) Bolts under 1 1/2 in. (38 mm) in diameter which require machined tests shall preferably use a standard 1/2 in., (13 mm) round 2 in. (51 mm) gage length test specimen (Fig. 5); however, bolts of small cross-section that will not permit the taking of this standard test specimen shall use one of the small-size-specimens-proportional-to-standard (Fig. 5) and the specimen shall have a reduced section as large as possible. In all cases, the longitudinal axis of the specimen shall be concentric with the axis of the bolt; the head and threaded section of the bolt may be left intact, as in Figs. A3.3 and A3.4, or shaped to fit the holders or grips of the testing machine so that the load is applied axially. The gage length for measuring the elongation shall be four times the diameter of the specimen.

(b) For bolts 1 1/2 in. and over in diameter, a standard 1/2 in. round 2 in. gage length test specimen shall be turned from the bolt, having its axis midway between the center and outside surface of the body of the bolt as shown in Fig. A3.5.

(c) Machined specimens are to be tested in tension to determine the properties prescribed by the product specifications. The methods of testing and determination of properties shall be in accordance with Section 13 of these test methods.

A3.3 Speed of Testing

A3.3.1 Speed of testing shall be as prescribed in the individual product specifications.

A3.4 Hardness Tests for Externally Threaded Fasteners

A3.4.1 When specified, externally threaded fasteners shall be hardness tested. Fasteners with hexagonal or square heads shall be Brinell or Rockwell hardness tested on the side or top of the head. Externally threaded fasteners with other type of heads and those without heads shall be Brinell or Rockwell hardness tested on the one end. Due to possible distortion from the Brinell load, care should be taken that this test meets the requirements of Section 16 of these test methods. Where the Brinell hardness test is impractical, the Rockwell hardness test shall be substituted. Rockwell hardness test procedures shall conform to Section 18 of these methods.

A3.4.2 In cases where a dispute exists between buyer and seller as to whether externally threaded fasteners meet or exceed the hardness limit of the product specifications for purposes of arbitration, hardness may be taken on two transverse sections through

a representative sample fastener selected at random. Hardness readings shall be taken at the locations show in Fig. A3.6. All hardness values must conform with the hardness limit of the product specification in order for the fasteners represented by the sample to be considered in compliance. This provision for arbitration of a dispute shall not be used to accept clearly rejectable fasteners.

A3.5 Testing of Nuts

A3.5.1 *Proof Load* — A sample nut shall be assembled on a hardened threaded mandrel or on a bolt conforming to the particular specification. A load axial with the mandrel or bolt and equal to the specified proof load of the nut shall be applied. The nut shall resist this load without stripping or rupture. If the threads of the mandrel are damaged during the test the individual test shall be discarded. The mandrel shall be threaded to American National Standard Class 3 tolerance, except that the major diameter shall be the minimum major diameter with a tolerance of +0.002 in. (0.051 mm).

A3.5.2 *Hardness Test* — Rockwell hardness of nuts shall be determined on the top or bottom face of the nut. Brinell hardness shall be determined on the side of the nuts. Either method may be used at the option of the manufacturer, taking into account the size and grade of the nuts under test. When the standard Brinell hardness test results in deforming the nut it will be necessary to use a minor load or substitute a Rockwell hardness test.

A3.6 Bars Heat Treated or Cold Drawn for Use in the Manufacture of Studs, Nuts or Other Bolting Material

A3.6.1 When the bars, as received by the manufacturer, have been processed and proved to meet certain specified properties, it is not necessary to test the finished product when these properties have not been changed by the process of manufacture employed for the finished product.

A4. ROUND WIRE PRODUCTS

A4.1 Scope

A4.1.1 This supplement covers the apparatus, specimens and methods of testing peculiar to steel wire products which are not covered in the general section of Test Methods A 370.

A4.2 Apparatus

A4.2.1 *Gripping Devices* — Grips of either the wedge or snubbing types as shown in Figs. A4.1 and A4.2 shall be used (Note A4.1). When using grips of either type, care shall be taken that the axis of the test specimen is located approximately at the center line of the head of the testing machine (Note A4.2). When using wedge grips the liners used behind the grips shall be of the proper thickness.

NOTE A4.1 — Testing machines usually are equipped with wedge grips. These wedge grips, irrespective of the type of testing machine, may be referred to as the "usual type" of wedge grips. The use of fine (180 or 240) grit abrasive cloth in the "usual" wedge type grips, with the abrasive contacting the wire specimen, can be helpful in reducing specimen slipping and breakage at the grip edges at tensile loads up to about 1000 pounds. For tests of specimens of wire which are liable to be cut at the edges by the "usual type" of wedge grips, the snubbing type gripping device has proved satisfactory. For testing round wire, the use of cylindrical seat in the wedge gripping device is optional.

NOTE A4.2 — Any defect in a testing machine which may cause nonaxial application of load should be corrected.

A4.2.2 *Pointed Micrometer* — A micrometer with a pointed spindle and anvil suitable for reading the dimensions of the wire specimen at the fractured ends to the nearest 0.001 in. (0.025 mm) after breaking the specimen in the testing machine shall be used.

A4.3 Test Specimens

A4.3.1 Test specimens having the full cross-sectional area of the wire they represent shall be used. The standard gage length of the specimens shall be 10 in. (254 mm). However, if the determination of elongation values is not required, any convenient gage length is permissible. The total length of the specimens shall be at least equal to the gage length (10 in.) plus twice the length of wire required for the full use of the grip employed. For example, depending upon the type of testing machine and grips used, the minimum total length of specimen may vary from 14 to 24 in. (360 to 610 mm) for a 10 in. gage length specimen.

A4.3.2 Any specimen breaking in the grips shall be discarded and a new specimen tested.

A4.4 Elongation

A4.4.1 In determining permanent elongation, the ends of the fractured specimen shall be carefully fitted together and the distance between the gage marks measured to the nearest 0.01 in. (0.25 mm) with dividers and scale or other suitable device. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In recording

elongation values, both the percentage increase and the original gage length shall be given.

A4.4.2 In determining total elongation (elastic plus plastic extension) autographic or extensometer methods may be employed.

A4.4.3 If fracture takes place outside of the middle third of the gage length, the elongation value obtained may not be representative of the material.

A4.5 Reduction of Area

A4.5.1 The ends of the fractured specimen shall be carefully fitted together and the dimensions of the smallest cross section measured to the nearest 0.001 in. (0.025 mm) with a pointed micrometer. The difference between the area thus found and the area of the original cross section, expressed as a percentage of the original area, is the reduction of area.

A4.5.2 The reduction of area test is not recommended in wire diameters less than 0.092 in. (2.34 mm) due to the difficulties of measuring the reduced cross sections.

A4.6 Rockwell Hardness Test

A4.6.1 With the exception of heat-treated wire of diameter 0.100 in. (2.54 mm) and larger, the Rockwell hardness test is not recommended for round wire. On such heat-treated wire the specimen shall be flattened on two parallel sides by grinding. For round wire the tensile strength test is greatly to be preferred to the Rockwell hardness test.

A4.7 Wrap Test

A4.7.1 This test is used as a means for testing the ductility of certain kinds of wire.

A4.7.2 The test consists of coiling the wire in a closely spaced helix tightly against a mandrel of a specified diameter for a required number of turns. (Unless other specified, the required number of turns shall be five.) The wrapping may be done by hand or a power device. The wrapping rate may not exceed 15 turns per min. The mandrel diameter shall be specified in the relevant wire product specification.

A4.7.3 The wire tested shall be considered to have failed if the wire fractures or if any longitudinal or transverse cracks develop which can be seen by the unaided eye after the first complete turn. Wire which fails in the first turn shall be retested, as such fractures may be caused by bending the wire to a radius less than specified when the test starts.

A4.8 Coiling Test

A4.8.1 This test is used to determine if imperfections are present to the extent that they may cause cracking or splitting during spring coiling and spring extension. A coil of specified length is closed wound on an arbor of a specified diameter. The closed coil is then stretched to a specified permanent increase in length and examined for uniformity of pitch with no splits or fractures. The required arbor diameter, closed coil length, and permanent coil extended length increase may vary with wire diameter, properties, and type.

A5. NOTES ON SIGNIFICANCE OF NOTCHED-BAR IMPACT TESTING

A5.1 Notch Behavior

A5.1.1 The Charpy and Izod type tests bring out notch behavior (brittleness versus ductility) by applying a single overload of stress. The energy values determined are quantitative comparisons on a selected specimen but cannot be converted into energy values that would serve for engineering design calculations. The notch behavior indicated in an individual test applies only to the specimen size, notch geometry, and testing conditions involved and cannot be generalized to other sizes of specimens and conditions.

A5.1.2 The notch behavior of the face-centered cubic metals and alloys, a large group of nonferrous materials and the austenitic steels can be judged from their common tensile properties. If they are brittle in tension they will be brittle when notched, while if they are ductile in tension, they will be ductile when notched, except for unusually sharp or deep notches (much more severe than the standard Charpy or Izod specimens). Even low temperatures do not alter this characteristic of these materials. In contrast, the behavior of the ferritic steels under notch conditions cannot be predicted from their properties as revealed by the tension test. For the study of these materials the Charpy and Izod type tests are accordingly very useful. Some metals that display normal ductility in the tension test may nevertheless break in brittle fashion when tested or when used in the notched condition. Notched conditions include restraints to deformation in directions perpendicular to the major stress, or multiaxial stresses, and stress concentrations. It is in this field that the Charpy and Izod tests prove useful for determining the susceptibility of a steel to notch-brittle behavior though they cannot be directly used to appraise the serviceability of a structure.

A5.1.3 The testing machine itself must be sufficiently rigid or tests on high-strength low-energy materials will result in excessive elastic energy losses either upward through the pendulum shaft or downward through the base of the machine. If the anvil supports, the pendulum striking edge, or the machine foundation bolts are not securely fastened, tests on ductile materials in the range of 80 ft·lbf (108 J) may actually indicate values in excess of 90 to 100 ft·lbf (122 to 136 J).

A5.2 Notch Effect

A5.2.1 The notch results in a combination of multiaxial stresses associated with restraints to deformation in directions perpendicular to the major stress, and a stress concentration at the base of the notch. A severely notched condition is generally not desirable, and it becomes of real concern in those cases in which it initiates a sudden and complete failure of the brittle type. Some metals can be deformed in a ductile manner even down to the low temperatures of liquid air, while others may crack. This difference in behavior can be best understood by considering the cohesive strength of a material (or the property that holds it together) and its relation to the yield point. In cases of brittle fracture, the cohesive strength is exceeded before significant plastic deformation occurs and the fracture appears crystalline. In cases of the ductile or shear type of failure, considerable deformation precedes the final fracture and the broken surface appears fibrous instead of crystalline. In intermediate cases the fracture comes after a moderate amount of deformation and is part crystalline and part fibrous in appearance.

A5.2.2 When a notched bar is loaded, there is a normal stress across the base of the notch which tends to initiate fracture. The property that keeps it from cleaving, or holds it together, is the "cohesive strength." The bar fractures when the normal stress exceeds the cohesive strength. When this occurs without the bar deforming it is the condition for brittle fracture.

A5.2.3 In testing, though not in service because of side effects, it happens more commonly that plastic deformation precedes fracture. In addition to the normal stress, the applied load also sets up shear stresses which are about 45° to the normal stress. The elastic behavior terminates as soon as the shear stress exceeds the shear strength of the material and deformation or plastic yielding sets in. This is the condition for ductile failure.

A5.2.4 This behavior, whether brittle or ductile, depends on whether the normal stress exceeds the cohesive strength before the shear stress exceeds the shear strength. Several important facts of notch behavior follow from this. If the notch is made sharper or more drastic, the normal stress at the root of the notch will be increased in relation to the shear stress and the bar will be more prone to brittle fracture (see Table A5.1). Also, as the speed of deformation increases, the shear strength increases and the likelihood of brittle fracture increases. On the other hand, by raising the temperature, leaving the notch and the speed of deformation the same, the shear strength is lowered and ductile behavior is promoted, leading to shear failure.

A5.2.5 Variations in notch dimensions will seriously affect the results of the tests. Tests on E 4340 steel specimens have shown the effect of dimensional variations on Charpy results (see Table A5.1).

A5.3 Size Effect

A5.3.1 Increasing either the width or the depth of the specimen tends to increase the volume of metal subject to distortion, and by this factor tends to increase the energy absorption when breaking the specimen. However, any increase in size, particularly in width, also tends to increase the degree of restraint and by tending to induce brittle fracture, may decrease the amount of energy absorbed. Where a standard-size specimen is on the verge of brittle fracture, this is particularly true, and a double-width specimen may actually require less energy for rupture than one of standard width.

A5.3.2 In studies of such effects where the size of the material precludes the use of the standard specimen, as for example when the material is $\frac{1}{4}$ in. plate, subsize specimens are necessarily used. Such specimens (see Fig. 6 of Test Methods E 23) are based on the Type A specimen of Fig. 4 of Test Methods E 23.

A5.3.3 General correlation between the energy values obtained with specimens of different size or shape is not feasible, but limited correlations may be established for specification purposes on the basis of special studies of particular materials and particular specimens. On the other hand, in a study of the relative effect of process variations, evaluation by use of some arbitrarily selected specimen with some chosen notch will in most instances place the methods in their proper order.

A5.4 Effects of Testing Conditions

A5.4.1 The testing conditions also affect the notch behavior. So pronounced is the effect of temperature on the behavior of steel when notched that comparisons are frequently made by examining specimen fractures and by plotting energy value and fracture appearance versus temperature from tests of notched bars at a

series of temperatures. When the test temperature has been carried low enough to start cleavage fracture, there may be an extremely sharp drop in impact value or there may be a relatively gradual falling off toward the lower temperatures. This drop in energy value starts when a specimen begins to exhibit some crystalline appearance in the fracture. The transition temperature at which this embrittling effect takes place varies considerably with the size of the part or test specimen and with the notch geometry.

A5.4.2 Some of the many definitions of transition temperature currently being used are: (1) the lowest temperature at which the specimen exhibits 100% fibrous fracture, (2) the temperature where the fracture shows a 50% crystalline and a 50% fibrous appearance, (3) the temperature corresponding to the energy value 50% of the difference between values obtained at 100% and 0% fibrous fracture, and (4) the temperature corresponding to a specific energy value.

A5.4.3 A problem peculiar to Charpy-type tests occurs when high-strength, low-energy specimens are tested at low temperatures. These specimens may not leave the machine in the direction of the pendulum swing but rather in a sidewise direction. To ensure that the broken halves of the specimens do not rebound off some component of the machine and contact the pendulum before it completes its swing, modifications may be necessary in older model machines. These modifications differ with machine design. Nevertheless the basic problem is the same in that provisions must be made to prevent rebounding of the fractured specimens into any part of the swinging pendulum. Where design permits, the broken specimens may be deflected out of the sides of the machine and yet in other designs it may be necessary to contain the broken specimens within a certain area until the pendulum passes through the anvils. Some low-energy high-strength steel specimens leave impact machines at speeds in excess of 50 ft (15.3 m)/s although they were struck by a pendulum traveling at speeds approximately 17 ft (5.2 m)/s. If the force exerted on the pendulum by the broken specimens is sufficient, the pendulum will slow down and erroneously high energy values will be recorded. This problem accounts for many of the inconsistencies in Charpy results reported by various investigators within the 10 to 25-ft · lbf (14 to 34 J) range. The Apparatus Section (the paragraph regarding Specimen Clearance) of Test Methods E 23 discusses the two basic machine designs and a modification found to be satisfactory in minimizing jamming.

A5.5 Velocity of Straining

A5.5.1 Velocity of straining is likewise a variable that affects the notch behavior of steel. The impact test shows somewhat higher energy absorption values than the static tests above the transition temperature and yet, in some instances, the reverse is true below the transition temperature.

A5.6 Correlation with Service

A5.6.1 While Charpy or Izod tests may not directly predict the ductile or brittle behavior of steel as commonly used in large masses or as components of large structures, these tests can be used as acceptance tests of identity for different lots of the same steel or in choosing between different steels, when correlation with reliable service behavior has been established. It may be necessary to make the tests at properly chosen temperatures other than room temperature. In this, the service temperature or the transition temperature of full-scale specimens does not give the desired transition temperatures for Charpy or Izod tests since the size and notch geometry may be so different. Chemical analysis, tension, and hardness tests may not indicate the influence of some of the important processing factors that affect susceptibility to brittle fracture nor do they comprehend the effect of low temperatures in inducing brittle behavior.

A6. PROCEDURE FOR CONVERTING PERCENTAGE ELONGATION OF A STANDARD ROUND TENSION TEST SPECIMEN TO EQUIVALENT PERCENTAGE ELONGATION OF A STANDARD FLAT SPECIMEN

A6.1 Scope

A6.1.1 This method specifies a procedure for converting percentage elongation after fracture obtained in a standard 0.500 in. (12.7 mm) diameter by 2 in. (51 mm) gage length test specimen to standard flat test specimens ½ in. by 2 in. and 1½ in. by 8 in. (38.1 by 203 mm).

A6.2 Basic Equation

A6.2.1 The conversion data in this method are based on an equation by Bertella, and used by Oliver and others. The relationship between elongations in the standard 0.500 in. diameter by 2.0 in. test specimen and other standard specimens can be calculated as follows:

$$e = e_o\,[4.47\,(\sqrt{A})/\mathrm{L}]^a$$

where:

e_o = percentage elongation after fracture on a standard test specimen having a 2 in. gage length and 0.500 in. diameter,

e = percentage elongation after fracture on a standard test specimen having a gage length L and a cross-sectional area A, and

a = constant characteristics of the test material.

A6.3 Application

A6.3.1 In applying the above equation the constant a is characteristic of the test material. The value $a = 0.4$ has been found to give satisfactory conversions for carbon, carbon-manganese, molybdenum, and chromium-molybdenum steels within the tensile strength range of 40,000 to 85,000 psi (275 to 585 MPa) and in the hot-rolled, in the hot-rolled and normalized, or in the annealed condition, with or without tempering. Note that the cold reduced and quenched and tempered states are excluded. For annealed austenitic stainless steels, the value $a = 0.127$ has been found to give satisfactory conversions.

A6.3.2 Table A6.1 has been calculated taking $a = 0.4$, with the standard 0.500 in. (12.7 mm) diameter by 2 in. (51 mm) gage length test specimen as the reference specimen. In the case of the subsize specimens 0.350 in. (8.89 mm) in diameter by 1.4 in. (35.6 mm) gage length, and 0.250 in. (6.35 mm) diameter by 1.0 in. (25.4 mm) gage length the factor in the equation is 4.51 instead of 4.47. The small error introduced by using Table A6.1 for the subsized specimens may be neglected. Table A6.2 for annealed austenitic steels has been calculated taking $a = 0.127$, with the standard 0.500 in. diameter by 2 in. gage length test specimen as the reference specimen.

A6.3.3 Elongation given for a standard 0.500 in. diameter by 2 in. gage length specimen may be converted to elongation for ½ in. by 2 in. or 1½ in. by 8 in. (38.1 by 203 mm) flat specimens by multiplying by the indicated factor in Tables A6.1 and A6.2.

A6.3.4 These elongation conversions shall not be used where the width to thickness ratio of the test piece exceeds 20, as in sheet specimens under 0.025 in. (0.635 mm) in thickness.

A6.3.5 While the conversions are considered to be reliable within the stated limitations and may generally be used in specification writing where it is desirable to show equivalent elongation requirements for the several standard ASTM tension specimens covered in Test Methods A 370, consideration must be given to the metallurgical effects dependent on the thickness of the material as processed.

A7. METHOD OF TESTING MULTI-WIRE STRAND FOR PRESTRESSED CONCRETES

A7.1 Scope

A7.1.1 This method provides procedures for the tension testing of multi-wire strand for prestressed concrete. This method is intended for use in evaluating the strand properties prescribed in specifications for "prestressing steel strands."

A7.2 General Precautions

A7.2.1 Premature failure of the test specimens may result if there is any appreciable notching, cutting, or bending of the specimen by the gripping devices of the testing machine.

A7.2.2 Errors in testing may result if the seven wires constituting the strand are not loaded uniformly.

A7.2.3 The mechanical properties of the strand may be materially affected by excessive heating during specimen preparation.

A7.2.4 These difficulties may be minimized by following the suggested methods of gripping described in A7.4.

A7.3 Gripping Devices

A7.3.1 The true mechanical properties of the strand are determined by a test in which fracture of the specimen occurs in the free span between the jaws of the testing machine. Therefore, it is desirable to establish a test procedure with suitable apparatus which will consistently produce such results. Due to inherent physical characteristics of individual machines, it is not practical to recommend a universal gripping procedure that is suitable for all testing machines. Therefore, it is necessary to determine which of the methods of gripping described in A7.3.2 to A7.3.8 is most suitable for the testing equipment available.

A7.3.2 *Standard V-Grips with Serrated Teeth (Note A7.1).*

A7.3.3 *Standard V-Grips with Serrated Teeth (Note A7.1), Using Cushioning Material* — In this method, some material is placed between the grips and the specimen to minimize the notching effect of the teeth. Among the materials which have been used are lead foil, aluminum foil, carborundum cloth, bra shims, etc.

The type and thickness of material required is dependent on the shape, condition, and coarseness of the teeth.

A7.3.4 *Standard V-Grips with Serrated Teeth (Note A7.1), Using Special Preparation of the Gripped Portions of the Specimen* — One of the methods used is tinning, in which the gripped portions are cleaned, fluxed, and coated by multiple dips in molten tin alloy held just above the melting point. Another method of preparation is encasing the gripped portions in metal tubing or flexible conduit, using epoxy resin as the bonding agent. The encased portion should be approximately twice the length of lay of the strand.

A7.3.5 *Special Grips with Smooth, Semi-Cylindrical Grooves (Note A7.2)* — The grooves and the gripped portions of the specimen are coated with an abrasive slurry which holds the specimen in the smooth grooves, preventing slippage. The slurry consists of abrasive such as Grade 3-F aluminum oxide and a carrier such as water or glycerin.

A7.3.6 *Standard Sockets of the Type Used for Wire Rope* — The gripped portions of the specimen are anchored in the sockets with zinc. The special procedures for socketing usually employed in the wire rope industry must be followed.

A7.3.7 *Dead-End Eye Splices* — These devices are available in sizes designed to fit each size of strand to be tested.

A7.3.8 *Chucking Devices* — Use of chucking devices of the type generally employed for applying tension to strands in casting beds is not recommended for testing purposes.

NOTE A7.1 — The number of teeth should be approximately 15 to 30 per in., and the minimum effective gripping length should be approximately 4 in. (102 mm).

NOTE A7.2 — The radius of curvature of the grooves is approximately the same as the radius of the strand being tested, and is located $\frac{1}{32}$ in. (0.79 mm) above the flat face of the grip. This prevents the two grips from closing tightly when the specimen is in place.

A7.4 Specimen Preparation

A7.4.1 If the molten-metal temperatures employed during hot-dip tinning or socketing with metallic material are too high, over approximately 700°F (370°C), the specimen may be heat affected with a subsequent loss of strength and ductility. Careful temperature controls should be maintained if such methods of specimen preparation are used.

A7.5 Procedure

A7.5.1 *Yield Strength* — For determining the yield strength use a Class B-1 extensometer (Note A7.3) as described in Practice E 83. Apply an initial load of 10% of the expected minimum breaking strength to the specimen, then attach the extensometer and adjust it to a reading of 0.001 in./in. of gage length. Then increase the load until the extensometer indicates an extension of 1%. Record the load for this extension as the yield strength. The extensometer may be removed from the specimen after the yield strength has been determined.

A7.5.2 *Elongation* — For determining the elongation use a Class D extensometer (Note A7.3), as described in Practice E 83, having a gage length of not less than 24 in. (610 mm) (Note A7.4). Apply an initial load of 10% of the required minimum breaking strength to the specimen, then attach the extensometer (Note A7.3) and adjust it to a zero reading. The extensometer may be removed from the specimen prior to rupture after the specified minimum elongation has been exceeded. It is not necessary to determine the final elongation value.

A7.5.3 *Breaking Strength* — Determine the maximum load at which one or more wires of the strand are fractured. Record this load as the breaking strength of the strand.

NOTE A7.3 — The yield-strength extensometer and the elongation extensometer may be the same instrument or two separate instruments. Two separate instruments are advisable since the more sensitive yield-strength extensometer, which could be damaged when the strand fractures, may be removed following the determination of yield strength. The elongation extensometer may be constructed with less sensitive parts or be constructed in such a way that little damage would result if fracture occurs while the extensometer is attached to the specimen.

NOTE A7.4 — Specimens that break outside the extensometer or in the jaws and yet meet the minimum specified values are considered as meeting the mechanical property requirements of the product specification, regardless of what procedure of gripping has been used. Specimens that break outside of the extensometer or in the jaws and do not meet the minimum specified values are subject to retest. Specimens that break between the jaws and extensometer and do not meet the minimum specified values are subject to retest as provided in the applicable specification.

A8. ROUNDING OF TEST DATA

A8.1 Rounding

A8.1.1 An observed value or a calculated value shall be rounded off in accordance with the applicable product specification. In the absence of a specified procedure, the rounding-off method of Practice E 29 shall be used.

A8.1.1.1 Values shall be rounded up or rounded down as determined by the rules of Practice E 29.

A8.1.1.2 In the special case of rounding the number "5" when no additional numbers other than "0" follow the "5," rounding shall be done in the direction of the specification limits if following Practice E 29 would cause rejection of material.

A8.1.2 Recommended levels for rounding reported values of test data are given in Table A8.1. These values are designed to provide uniformity in reporting and data storage, and should be used in all cases except where they conflict with specific requirements of a product specification.

NOTE A8.1 — To minimize cumulative errors, whenever possible, values should be carried to at least one figure beyond that of the final (rounded) value during intervening calculations (such as calculation of stress from load and area measurements) with rounding occurring as the final operation. The precision may be less than that implied by the number of significant figures.

A9. METHODS FOR TESTING STEEL REINFORCING BARS

A9.1 Scope

A9.1.1 This annex covers additional details specific to testing steel reinforcing bars for use in concrete reinforcement.

A9.2 Test Specimens

A9.2.1 All test specimens shall be the full section of the bar as rolled.

A9.3 Tension Testing

A9.3.1 *Test Specimen* — Specimens for tension tests shall be long enough to provide for an 8 in. (200 mm) gage length, a distance of at least two bar diameters between each gage mark and the grips, plus sufficient additional length to fill the grips completely leaving some excess length protruding beyond each grip.

A9.3.2 *Gripping Device* — The grips shall be shimmed so that no more than ½ in. (13 mm) of a grip protrudes from the head of the testing machine.

A9.3.3 *Gage Marks* — The 8 in. (200 mm) gage length shall be marked on the specimen using a preset 8 in. (200 mm) punch or, alternately, may be punch marked every 2 in. (50 mm) along the 8 in. (200 mm) gage length, on one of the longitudinal ribs, if present, or in clear spaces of the deformation pattern. The punch marks shall not be put on a transverse deformation. Light punch marks are desirable because deep marks severely indent the bar and may affect the results. A bullet-nose punch is desirable.

A9.3.4 The yield strength or yield point shall be determined by one of the following methods:

A9.3.4.1 Extension under load using an autographic diagram method or an extensometer as described in 13.1.2 and 13.1.3,

A9.3.4.2 By the drop of the beam or halt in the gage of the testing machine as described in 13.1.1 where the steel tested as a sharp-kneed or well-defined type of yield point.

A9.3.5 The unit stress determinations for yield and tensile strength on full-size specimens shall be based on the nominal bar area.

A9.4 Bend Testing

A9.4.1 Bend tests shall be made on specimens of sufficient length to ensure free bending and with apparatus which provides:

A9.4.1.1 Continuous and uniform application of force throughout the duration of the bending operation,

A9.4.1.2 Unrestricted movement of the specimen at points of contact with the apparatus and bending around a pin free to rotate, and

A9.4.1.3 Close wrapping of the specimen around the pin during the bending operation.

A9.4.2 Other acceptable more severe methods of bend testing, such as placing a specimen across two pins free to rotate and applying the bending force with a fix pin, may be used.

A9.4.3 When re-testing is permitted by the product specification, the following shall apply:

A9.4.3.1 Sections of bar containing identifying roll marking shall not be used.

A9.4.3.2 Bars shall be so placed that longitudinal ribs lie in a plane at right angles to the plane of bending.

A10. PROCEDURE FOR USE AND CONTROL OF HEAT-CYCLE SIMULATION

A10.1 Purpose

A10.1.1 To ensure consistent and reproducible heat treatments of production forgings and the test specimens that represent them when the practice of heat-cycle simulation is used.

A10.2 Scope

A10.2.1 Generation and documentation of actual production time–temperature curves (MASTER CHARTS).

A10.2.2 Controls for duplicating the master cycle during heat treatment of production forgings. (Heat treating within the essential variables established during A1.2.1.)

A10.2.3 Preparation of program charts for the simulator unit.

A10.2.4 Monitoring and inspection of the simulated cycle within the limits established by the ASME Code.

A10.2.5 Documentation and storage of all controls, inspections, charts, and curves.

A10.3 Referenced Documents

A10.3.1 *ASME Standards:*

ASME Boiler and Pressure Vessel Code Section III, latest edition.

ASME Boiler and Pressure Vessel Code Section VIII, Division 2, latest edition.

A10.4 Terminology

A10.4.1 *Definitions:*

A10.4.1.1 *master chart* — a record of the heat treatment received from a forging essentially identical to the production forgings that it will represent. It is a chart of time and temperature showing the output from thermocouples imbedded in the forging at the designated test immersion and test location or locations.

A10.4.1.2 *program chart* — the metallized sheet used to program the simulator unit. Time–temperature data from the master chart are manually transferred to the program chart.

A10.4.1.3 *simulator chart* — a record of the heat treatment that a test specimen had received in the simulator unit. It is a chart of time and temperature and can be compared directly to the master chart for accuracy of duplication.

A10.4.1.4 *simulator cycle* — one continuous heat treatment of a set of specimens in the simulator unit. The cycle includes heating from ambient, holding at temperature, and cooling. For example, a simulated austenitize and quench of a set of specimens would be one cycle; a simulated temper of the same specimens would be another cycle.

A10.5 Procedure

A10.5.1 *Production Master Charts:*

A10.5.1.1 Thermocouples shall be imbedded in each forging from which a master chart is obtained. Temperature shall be monitored by a recorder with resolution sufficient to clearly define all aspects of the heating, holding, and cooling process. All charts are to be clearly identified with all pertinent information and identification required for maintaining permanent records.

A10.5.1.2 Thermocouples shall be imbedded 180 deg apart if the material specification requires test locations 180 deg apart.

A10.5.1.3 One master chart (or two if required in accordance with A1.5.1.2) shall be produced to represent essentially identical forgings (same size and shape). Any change in size or geometry (exceeding rough machining tolerances) of a forging will necessitate that a new master cooling curve be developed.

A10.5.1.4 If more than one curve is required per master forging (180 deg apart) and a difference in cooling rate is achieved, then the most conservative curve shall be used as the master curve.

A10.5.2 *Reproducibility of Heat Treatment Parameters on Production Forgings:*

A10.5.2.1 All information pertaining to the quench and temper of the master forging shall be recorded on an appropriate permanent record, similar to the one shown in Table A10.1.

A10.5.2.2 All information pertaining to the quench and temper of the production forgings shall be appropriately recorded, preferably on a form similar to that used in A10.5.2.1. Quench records of production forgings shall be retained for future reference. The quench and temper record of the master forging shall be retained as a permanent record.

A10.5.2.3 A copy of the master forging record shall be stored with the heat treatment record of the production forging.

A10.5.2.4 The essential variables, as set forth on the heat treat record, shall be controlled within the given parameters on the production forging.

A10.5.2.5 The temperature of the quenching medium prior to quenching each production forging shall be equal to or lower than the temperature of

the quenching medium prior to quenching the master forging.

A10.5.2.6 The time elapsed from opening the furnace door to quench for the production forging shall not exceed that elapsed for the master forging.

A10.5.2.7 If the time parameter is exceeded in opening the furnace door to beginning of quench, the forging shall be placed back into the furnace and brought back up to equalization temperature.

A10.5.2.8 All forgings represented by the same master forging shall be quenched with like orientation to the surface of the quench bath.

A10.5.2.9 All production forgings shall be quenched in the same quench tank, with the same agitation as the master forging.

A10.5.2.10 *Uniformity of Heat Treat Parameters* — (1) The difference in actual heat treating temperature between production forgings and the master forging used to establish the simulator cycle for them shall not exceed ±25°F (±14°C) for the quench cycle. (2) The tempering temperature of the production forgings shall not fall below the actual tempering temperature of the master forging. (3) At least one contact surface thermocouple shall be placed on each forging in a production load. Temperature shall be recorded for all surface thermocouples on a Time Temperature Recorder and such records shall be retained as permanent documentation.

A10.5.3 *Heat-Cycle Simulation:*

A10.5.3.1 Program charts shall be made from the data recorded on the master chart. All test specimens shall be given the same heating rate above, the AC1, the same holding time and the same cooling rate as the production forgings.

A10.5.3.2 The heating cycle above the AC1, a portion of the holding cycle, and the cooling portion of the master chart shall be duplicated and the allowable limits on temperature and time, as specified in (a)–(c), shall be established for verification of the adequacy of the simulated heat treatment.

(a) Heat Cycle Simulation of Test Coupon Heat Treatment for Quenched and Tempered Forgings and Bars — If cooling rate data for the forgings and bars and cooling rate control devices for the test specimens are available, the test specimens may be heat-treated in the device.

(b) The test coupons shall be heated to substantially the same maximum temperature as the forgings or bars. The test coupons shall be cooled at a rate similar to and no faster than the cooling rate representative of the test locations and shall be within 25°F (14°C) and 20 s at all temperatures after cooling begins. The test coupons shall be subsequently heat treated in accordance with the thermal treatments below the critical temperature including tempering and simulated post weld heat treatment.

(c) Simulated Post Weld Heat Treatment of Test Specimens (for ferritic steel forgings and bars) — Except for carbon steel (P Number 1, Section IX of the Code) forgings and bars with a nominal thickness or diameter of 2 in. (51 mm) or less, the test specimens shall be given a heat treatment to simulate any thermal treatments below the critical temperature that the forgings and bars may receive during fabrication. The simulated heat treatment shall utilize temperatures, times, and cooling rates as specified on the order. The total time at temperature(s) for the test material shall be at least 80% of the total time at temperature(s) to which the forgings and bars are subjected during post-weld heat treatment. The total time at temperature(s) for the test specimens may be performed in a single cycle.

A10.5.3.3 Prior to heat treatment in the simulator unit, test specimens shall be machined to standard sizes that have been determined to allow adequately for subsequent removal of decarb and oxidation.

A10.5.3.4 At least one thermocouple per specimen shall be used for continuous recording of temperature on an independent external temperature-monitoring source. Due to the sensitivity and design peculiarities of the heating chamber of certain equipment, it is mandatory that the hot junctions of control and monitoring thermocouples always be placed in the same relative position with respect to the heating source (generally infra red lamps).

A10.5.3.5 Each individual specimen shall be identified, and such identification shall be clearly shown on the simulator chart and simulator cycle record.

A10.5.3.6 The simulator chart shall be compared to the master chart for accurate reproduction of simulated quench in accordance with A1.5.3.2(a). If any one specimen is not heat treated within the acceptable limits of temperature and time, such specimen shall be discarded and replaced by a newly machined specimen. Documentation of such action and reasons for deviation from the master chart shall be shown on the simulator chart, and on the corresponding nonconformance report.

A10.5.4 *Reheat Treatment and Retesting:*

A10.5.4.1 In the event of a test failure, retesting shall be handled in accordance with rules set forth by the material specification.

A10.5.4.2 If retesting is permissible, a new test specimen shall be heat treated the same as previously. The production forging that it represents will have received the same heat treatment. If the test passes, the forging shall be acceptable. If it fails, the forging shall be rejected or shall be subject to reheat treatment if permissible.

A10.5.4.3 If reheat treatment is permissible, proceed as follows: (1) Reheat treatment same as original heat treatment (time, temperature, cooling rate): Using new test specimens from an area as close as possible to the original specimens, repeat the austenitize and quench cycles twice, followed by the tempering cycle (double quench and temper). The production forging shall be given the identical double quench and temper as its test specimens above. (2) Reheat treatment using a new heat treatment practice. Any change in time, temperature, or cooling rate shall constitute a new heat treatment practice. A new master curve shall be produced and the simulation and testing shall proceed as originally set forth.

A10.5.4.4 In summation, each test specimen and its corresponding forging shall receive identical heat treatment or heat treatment; otherwise the testing shall be invalid.

A10.5.5 *Storage, Recall, and Documentation of Heat-Cycle Simulation Data* — All records pertaining to heat-cycle simulation shall be maintained and held for a period of 10 years or as designed by the customer. Information shall be so organized that all practices can be verified by adequate documented records.

TABLE A1.1
PRACTICES FOR SELECTING TENSION TEST SPECIMENS FOR STEEL BAR PRODUCTS

NOTE — For bar sections where it is difficult to determine the cross-sectional area by simple measurement, the area in square inches may be calculated by dividing the weight per linear inch of specimen in pounds by 0.2833 (weight of 1 in.^{3} of steel) or by dividing the weight per linear foot of specimen by 3.4 (weight of steel 1 in. square and 1 ft long).

Thickness, in. (mm)	Width, in. (mm)	Hot-Rolled Bars	Cold-Finished Bars
		Flats	
Under 5/8 (16)	Up to 1 1/2 (38), incl	Full section by 8-in. (203-mm) gage length (Fig. 4).	Mill reduced section to 2-in. (51-mm) gage length and approximately 25% less than test specimen width.
	Over 1 1/2 (38)	Full section, or mill to 1 1/2 in. (38 mm) wide by 8-in. (203-mm) gage length (Fig. 4).	Mill reduced section to 2-in. gage length and 1 1/2 in. wide.
5/8 to 1 1/2 (16 to 38), excl	Up to 1 1/2 (38), incl	Full section by 8-in. gage length or machine standard 1/2 by 2-in. (13 by 51-mm) gage length specimen from center of section (Fig. 5).	Mill reduced section to 2-in. (51-mm) gage length and approximately 25% less than test specimen width or machine standard 1/2 by 2-in. (13 by 51-mm) gage length specimen from center of section (Fig. 5).
	Over 1 1/2 (38)	Full section, or mill 1 1/2 in. (38 mm) width by 8-in. (203-mm) gage length (Fig. 4) or machine standard 1/2 by 2-in. gage (13 by 51-mm) gage length specimen from midway between edge and center of section (Fig. 5).	Mill reduced section to 2-in. gage length and 1 1/2 in. wide or machine standard 1/2 by 2-in. gage length specimen from midway between edge and center of section (Fig. 5).
1 1/2 (38) and over		Full section by 8-in. (203-mm) gage length, or machine standard 1/2 by 2-in. (13 by 51-mm) gage length specimen from midway between surface and center (Fig. 5).	Machine standard 1/2 by 2-in. (13 by 51-mm) gage length specimen from midway between surface and center (Fig. 5).

Diameter or Distance Between Parallel Faces, in. (mm)	Hot-Rolled Bars	Cold-Finished Bars
	Rounds, Squares, Hexagons, and Octagons	
Under 5/8	Full section by 8-in. (203-mm) gage length on machine to sub-size specimen (Fig. 5).	Machine to sub-size specimen (Fig. 5).
5/8 to 1 1/2 (16 to 38), excl	Full section by 8-in. (203-mm) gage length or machine standard 1/2 in. by 2-in. (13 by 51-mm) gage length specimen from center of section (Fig. 5).	Machine standard 1/2 in. by 2-in. gage length specimen from center of section (Fig. 5).
1 1/2 (38) and over	Full section by 8-in. (203-mm) gage length or machine standard 1/2 in. by 2-in. (13 by 51-mm) gage length specimen from midway between surface and center of section (Fig. 5).	Machine standard 1/2 by 2-in. (13 by 51-mm) gage length specimen from midway between surface and center of section (Fig. 5).
	Other Bar-Size Sections	
All sizes	Full section by 8-in. (203-mm) gage length or prepare test specimen 1 1/2 in. (38 mm) wide (if possible) by 8-in. (203-mm) gage length.	Mill reduced section to 2-in. (51-mm) gage length and approximately 25% less than test specimen width.

TABLE A1.2
RECOMMENDED PRACTICE FOR SELECTING BEND TEST SPECIMENS FOR STEEL BAR PRODUCTS

NOTE 1 — The length of all specimens is to be not less than 6 in. (150 mm).
NOTE 2 — The edges of the specimen may be rounded to a radius not exceeding $\frac{1}{16}$ in. (1.6 mm).

Flats		
Thickness, in. (mm)	Width, in. (mm)	Recommended Size
Up to $\frac{1}{2}$ (13), incl	Up to $\frac{3}{4}$ (19), incl	Full section.
	Over $\frac{3}{4}$ (19)	Full section or machine to not less than $\frac{3}{4}$ in. (19 mm) in width by thickness of specimen.
Over $\frac{1}{2}$ (13)	All	Full section or machine to 1 by $\frac{1}{2}$ in. (25 by 13 mm) specimen from midway between center and surface.

Rounds, Squares, Hexagons, and Octagons	
Diameter or Distance Between Parallel Faces, in. (mm)	Recommended Size
Up to $1\frac{1}{2}$ (38), incl	Full section.
Over $1\frac{1}{2}$ (38)	Machine to 1 by $\frac{1}{2}$-in. (25 by 13-mm) specimen from midway between center and surface.

TABLE A2.1
WALL THICKNESS LIMITATIONS OF SUPERFICIAL HARDNESS TEST ON ANNEALED OR DUCTILE MATERIALS FOR STEEL TUBULAR PRODUCTS[A]
("T" Scale ($\frac{1}{16}$-in. Ball))

Wall Thickness, in. (mm)	Load, kgf
Over 0.050 (1.27)	45
Over 0.035 (0.89)	30
0.020 and over (0.51)	15

[A] The heaviest load recommended for a given wall thickness is generally used.

TABLE A2.2
WALL THICKNESS LIMITATIONS OF SUPERFICIAL HARDNESS TEST ON COLD WORKED OR HEAT TREATED MATERIAL FOR STEEL TUBULAR PRODUCTS[A]
("N" Scale (Diamond Penetrator))

Wall Thickness, in. (mm)	Load, kgf
Over 0.035 (0.89)	45
Over 0.025 (0.51)	30
0.015 and over (0.38)	15

[A] The heaviest load recommended for a given wall thickness is generally used.

TABLE A5.1
EFFECT OF VARYING NOTCH DIMENSIONS ON STANDARD SPECIMENS

	High-Energy Specimens, ft · lbf (J)	High-Energy Specimens, ft · lbf (J)	Low-Energy Specimens, ft · lbf (J)
Specimen with standard dimensions	76.0 ± 3.8 (103.0 ± 5.2)	44.5 ± 2.2 (60.3 ± 3.0)	12.5 ± 1.0 (16.9 ± 1.4)
Depth of notch, 0.084 in. (2.13 mm)[A]	72.2 (97.9)	41.3 (56.0)	11.4 (15.5)
Depth of notch, 0.805 in. (2.04 mm)[A]	75.1 (101.8)	42.2 (57.2)	12.4 (16.8)
Depth of notch, 0.0775 in. (1.77 mm)[A]	76.8 (104.1)	45.3 (61.4)	12.7 (17.2)
Depth of notch, 0.074 in. (1.57 mm)[A]	79.6 (107.9)	46.0 (62.4)	12.8 (17.3)
Radius at base of notch, 0.005 in. (0.127 mm)[B]	72.3 (98.0)	41.7 (56.5)	10.8 (14.6)
Radius at base of notch, 0.015 in. (0.381 mm)[B]	80.0 (108.5)	47.4 (64.3)	15.8 (21.4)

[A] Standard 0.079 ± 0.002 in. (2.00 ± 0.05 mm).
[B] Standard 0.010 ± 0.001 in. (0.25 ± 0.025 mm).

TABLE A6.1
CARBON AND ALLOY STEELS — MATERIAL CONSTANT $a = 0.4$. MULTIPLICATION FACTORS FOR CONVERTING PERCENT ELONGATION FROM ½-IN. DIAMETER BY 2-IN. GAGE LENGTH STANDARD TENSION TEST SPECIMEN TO STANDARD ½ BY 2-IN. AND 1½ BY 8-IN. FLAT SPECIMENS

Thickness, in.	½ by 2-in. Specimen	1½ by 8-in. Specimen	Thickness, in.	1½ by 8-in. Specimen
0.025	0.574	. . .	0.800	0.822
0.030	0.596	. . .	0.850	0.832
0.035	0.614	. . .	0.900	0.841
0.040	0.631	. . .	0.950	0.850
0.045	0.646	. . .	1.000	0.859
0.050	0.660	. . .	1.125	0.880
0.055	0.672	. . .	1.250	0.898
0.060	0.684	. . .	1.375	0.916
0.065	0.695	. . .	1.500	0.932
0.070	0.706	. . .	1.625	0.947
0.075	0.715	. . .	1.750	0.961
0.080	0.725	. . .	1.875	0.974
0.085	0.733	. . .	2.000	0.987
0.090	0.742	0.531	2.125	0.999
0.100	0.758	0.542	2.250	1.010
0.110	0.772	0.553	2.375	1.021
0.120	0.786	0.562	2.500	1.032
0.130	0.799	0.571	2.625	1.042
0.140	0.810	0.580	2.750	1.052
0.150	0.821	0.588	2.875	1.061
0.160	0.832	0.596	3.000	1.070
0.170	0.843	0.603	3.125	1.079
0.180	0.852	0.610	3.250	1.088
0.190	0.862	0.616	3.375	1.096
0.200	0.870	0.623	3.500	1.104
0.225	0.891	0.638	3.625	1.112
0.250	0.910	0.651	3.750	1.119
0.275	0.928	0.664	3.875	1.127
0.300	0.944	0.675	4.000	1.134
0.325	0.959	0.686	. . .	. . .
0.350	0.973	0.696	. . .	. . .
0.375	0.987	0.706	. . .	. . .
0.400	1.000	0.715	. . .	. . .
0.425	1.012	0.724	. . .	. . .
0.450	1.024	0.732	. . .	. . .
0.475	1.035	0.740	. . .	. . .
0.500	1.045	0.748	. . .	. . .
0.525	1.056	0.755	. . .	. . .
0.550	1.066	0.762	. . .	. . .
0.575	1.075	0.770	. . .	. . .
0.600	1.084	0.776	. . .	. . .
0.625	1.093	0.782	. . .	. . .
0.650	1.101	0.788	. . .	. . .
0.675	1.110	. . .	. . .	. . .
0.700	1.118	0.800	. . .	. . .
0.725	1.126	. . .	. . .	. . .
0.750	1.134	0.811	. . .	. . .

TABLE A6.2
ANNEALED AUSTENITIC STAINLESS STEELS — MATERIAL CONSTANT $A = 0.127$. MULTIPLICATION FACTORS FOR CONVERTING PERCENT ELONGATION FROM ½-IN. DIAMETER BY 2-IN. GAGE LENGTH STANDARD TENSION TEST SPECIMEN TO STANDARD ½ BY 2-IN. AND 1½ BY 8-IN. FLAT SPECIMENS

Thickness, in.	½ by 2-in. Specimen	1½ by 8-in. Specimen	Thickness, in.	1½ by 8-in. Specimen
0.025	0.839	. . .	0.800	0.940
0.030	0.848	. . .	0.850	0.943
0.035	0.857	. . .	0.900	0.947
0.040	0.864	. . .	0.950	0.950
0.045	0.870	. . .	1.000	0.953
0.050	0.876	. . .	1.125	0.960
0.055	0.882	. . .	1.250	0.966
0.060	0.886	. . .	1.375	0.972
0.065	0.891	. . .	1.500	0.978
0.070	0.895	. . .	1.625	0.983
0.075	0.899	. . .	1.750	0.987
0.080	0.903	. . .	1.875	0.992
0.085	0.906	. . .	2.000	0.996
0.090	0.909	0.818	2.125	1.000
0.095	0.913	0.821	2.250	1.003
0.100	0.916	0.823	2.375	1.007
0.110	0.921	0.828	2.500	1.010
0.120	0.926	0.833	2.625	1.013
0.130	0.931	0.837	2.750	1.016
0.140	0.935	0.841	2.875	1.019
0.150	0.940	0.845	3.000	1.022
0.160	0.943	0.848	3.125	1.024
0.170	0.947	0.852	3.250	1.027
0.180	0.950	0.855	3.375	1.029
0.190	0.954	0.858	3.500	1.032
0.200	0.957	0.860	3.625	1.034
0.225	0.964	0.867	3.750	1.036
0.250	0.970	0.873	3.875	1.038
0.275	0.976	0.878	4.000	1.041
0.300	0.982	0.883	. . .	. . .
0.325	0.987	0.887	. . .	. . .
0.350	0.991	0.892	. . .	. . .
0.375	0.996	0.895	. . .	. . .
0.400	1.000	0.899	. . .	. . .
0.425	1.004	0.903	. . .	. . .
0.450	1.007	0.906	. . .	. . .
0.475	1.011	0.909	. . .	. . .
0.500	1.014	0.912	. . .	. . .
0.525	1.017	0.915	. . .	. . .
0.550	1.020	0.917	. . .	. . .
0.575	1.023	0.920	. . .	. . .
0.600	1.026	0.922	. . .	. . .
0.625	1.029	0.925	. . .	. . .
0.650	1.031	0.927	. . .	. . .
0.675	1.034	. . .	. . .	. . .
0.700	1.036	0.932	. . .	. . .
0.725	1.038	. . .	. . .	. . .
0.750	1.041	0.936	. . .	. . .

TABLE A8.1
RECOMMENDED VALUES FOR ROUNDING TEST DATA

Test Quality	Test Data Range	Rounded Value[A]
Yield Point Yield Strength, Tensile Strength	up to 50 000 psi, excl (up to 50 ksi)	100 psi (0.1 ksi)
	50 000 to 100 000 psi, excl (50 to 100 ksi)	500 psi (0.5 ksi)
	100 000 psi and above (100 ksi and above)	1000 psi (1.0 ksi)
	up to 500 MPa, excl	1 MPa
	500 to 1000 MPa, excl	5 MPa
	1000 MPa and above	10 MPa
Elongation	0 to 10%, excl	0.5%
	10% and above	1%
Reduction of Area	0 to 10%, excl	0.5%
	10% and above	1%
Impact Energy	0 to 240 ft · lbf (or 0 to 325 J)	1 ft · lbf (or 1 J)[B]
Brinell Hardness	all values	tabular value[C]
Rockwell Hardness	all values	1 Rockwell Number

[A] Round test data to the nearest integral multiple of the values in this column. If the data value is exactly midway between two rounded values, round in accordance with A8.1.1.2.

[B] These units are not equivalent but the rounding occurs in the same numerical ranges for each. (1 ft · lbf = 1.356 J).

[C] Round the mean diameter of the Brinell impression to the nearest 0.05 mm and report the corresponding Brinell hardness number read from the table without further rounding.

TABLE A10.1
HEAT-TREAT RECORD-ESSENTIAL VARIABLES

	Master Forging	Production Forging 1	Production Forging 2	Production Forging 3	Production Forging 4	Production Forging 5
Program chart number						
Time at temperature and actual temperature of heat treatment						
Method of cooling						
Forging thickness						
Thermocouple immersion						
Beneath buffer (yes/no)						
Forging number						
Product						
Material						
Thermocouple location — 0 deg						
Thermocouple location — 180 deg						
Quench tank No.						
Date of heat treatment						
Furnace number						
Cycle number						
Heat treater						
Starting quench medium temperature						
Time from furnace to quench						
Heating rate above 1000°F (538°C)						
Temperature upon removal from quench after 5 min						
Orientation of forging in quench						

SPECIFICATION FOR CARBON AND ALLOY STEEL FORGINGS FOR THIN-WALLED PRESSURE VESSELS

SA-372/SA-372M

(Identical with ASTM Specification A 372/A 372M-95, except for the additional requirements in 5.3.) A99

1. Scope

A99 **1.1** This specification covers relatively thin-walled forgings (including gas bottles) for pressure vessel use. Three types of carbon steel and six types of alloy steel are included. Provision is made for integrally forging the ends of vessel bodies made from seamless pipe or tubing.

NOTE 1—When working to the chemical and tensile requirements of this specification, the influence of wall thickness and cooling rate will necessarily eliminate certain forging sizes in each class.

NOTE 2—Designations have been changed as follows:

Current	Formerly
Grade A	Type I
Grade B	Type II
Grade C	Type III
Grade D	Type IV
Grade E Class 55	Type V Grade 1 Class 55
Grade E Class 65	Type V Grade 1 Class 65
Grade E Class 70	Type V Grade 1 Class 70
Grade F Class 55	Type V Grade 2 Class 55
Grade F Class 65	Type V Grade 2 Class 65
Grade F Class 70	Type V Grade 2 Class 70
Grade G Class 55	Type V Grade 3 Class 55
Grade G Class 65	Type V Grade 3 Class 65
Grade G Class 70	Type V Grade 3 Class 70
Grade H Class 55	Type V Grade 4 Class 55
Grade H Class 65	Type V Grade 4 Class 65
Grade H Class 70	Type V Grade 4 Class 70
Grade J Class 55	Type V Grade 5 Class 55
Grade J Class 65	Type V Grade 5 Class 65
Grade J Class 70	Type V Grade 5 Class 70
Grade K	Type VI
Grade L	Type VII
Grade J Class 110	Type VIII
Grade M Class A	Type IX Class A
Grade M Class B	Type IX Class B

1.2 The values stated in either inch-pound or SI [metric] units are to regarded separately as the standard. Within the text and the tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 Unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 788 Specification for Steel Forgings, General Requirements

E 112 Test Methods for Determining the Average Grain Size

E 165 Practice for Liquid Penetrant Examination

E 290 Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials

E 433 Referenced Photographs for Liquid Penetrant Inspection

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order a detailed drawing, sketch, or written description of the forging and the areas of significant loading in the forging when required (see 6.4.2.2).

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Melting Practice:*

4.1.1 The steel melting procedures of Specification A 788 shall apply except that for Grade M forgings, only steel that has been vacuum treated prior to or during the pouring of the ingot, in order to remove objectionable gases, particularly hydrogen, shall be used.

4.2 *Production Methods:*

4.2.1 Methods for the production of gas bottles and similar vessels may include the cupping of slabs or plates, the piercing of billets or plates, and the subsequent drawing of cups so produced. Such semi-finished forgings or seamless steel pipe or tubing may be closed by spinning, swedging, or pressing. In all cases there shall be sufficient discard to ensure soundness in the completed forging.

4.3 *Heat Treatment:*

4.3.1 At the option of the manufacturer, Grades A, B, C, D and Classes 55, 65, 70 of Grades E, F, G, H, and J forgings shall be normalized, normalized and tempered, or liquid-quenched and tempered.

4.3.2 Grades K, L, M, and Class 110 of Grade J forgings shall be liquid-quenched and tempered.

4.3.3 When normalized forgings are to be tempered, or when forgings have been quenched, they shall be reheated to a subcritical temperature and held for at least ½ h/in. [25 mm] of maximum cross section.

4.3.3.1 Minimum tempering temperatures shall be as follows: **98**

Grades E, F, G, H, J in Classes 55, 65, 70	1100°F [595°C]
Grade K	1100°F [595°C]
Grade L	1000°F [540°C]
Grade J Class 110	1000°F [540°C]
Grade M	1100°F [595°C]

4.3.4 All quenched and tempered forgings shall be subject to magnetic particle examination in accordance with Section 7.

5. Chemical Composition

5.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1.

5.2 *Product Analysis*—The purchaser may use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat.

5.3 Starting material produced to a specification that specifically requires the addition of any element beyond those listed in Table 1 for the applicable grade of material is not permitted. This does not preclude use of deoxidation or inclusion control additions. Supplementary Requirements S1 and S2 of Specification A 788 shall apply. **98**

6. Mechanical Properties

6.1 Mechanical tests for acceptance shall be made after the final heat treatment of the forgings.

6.2 *Tension Test*—When tested in accordance with Test Methods and Definitions A 370, the material shall conform to the requirements of Table 2. The yield strength shall be determined by the 0.2% offset method.

6.3 *Bending Properties*—Depending upon the outside diameter, D, and the wall thickness, *T*, of hollow or bored forgings, a bend test or flattening test will be required.

6.3.1 For bored or hollow forgings with outside diameters of 14 in. [355 mm] or less and with a *D/T* ratio of more than 10.0, a flattening test is required. This shall be carried out in accordance with Specification A 530/A 530M and Table 3. No breaks or cracks in the test ring are acceptable until the distance between the plates is less than that shown in Table 3.

6.3.2 For bored or hollow forgings with outside diameters 14 in. [355 mm], or where the *D/T* ratio is 10.0 or less at the manufacturer's option, the flattening test specified in 6.3.1, or a transverse bend test in accordance with Arrangement C of Test Method E 290 is required. The bend test pin diameter shall be as specified in Table 4. No cracks or ruptures in the test piece are allowable when the test piece is bent through the required angle.

6.4 *Orientation and Location of Test Specimens:*

6.4.1 Test specimens representing vessel bodies or shells shall be taken from a prolongation of a forging, from test rings that have been heat treated with the forgings they represent, or from a representative forging after heat treatment in accordance with 4.3.3.

6.4.1.1 Test specimens representing vessel bodies or shells shall be located at a position corresponding to the mid-wall location of the parallel side wall of the heat-treated forging and shall be oriented parallel to the longitudinal axis of the vessel.

6.4.1.2 A test ring shall be in the shape of a right circular cylinder having the same diameter and wall thickness as the cylinders it represents. In addition, the test ring shall be from the same heat of steel and be subjected to the same heat treatment as the cylinders it represents. The method of quenching the test ring must duplicate that of the cylinders; if the cylinders are quenched from the outside only, then the test ring must have its ends closed. The length of test rings that will be liquid quenched must be at least 24 in. [610 mm]. The ends of such test rings may be vented to prevent pressure buildup during heat treating.

6.4.2 Test specimens representing vessel covers or similar components may be taken from a full section prolongation of the cover, from a representative forging, or from an integral prolongation when the part is contour-machined prior to heat treatment.

6.4.2.1 Test specimens taken from full size prolongations or representative forgings shall be located at a position midway between the center and the surface.

6.4.2.2 When forgings are contour-machined prior to heat treatment so that highly stressed surfaces are exposed, the test specimens may be taken at an equal distance (*t*) from the nearest quenched surface as the highly stressed area, but not less than $\frac{3}{4}$ in. [20 mm]. The location of the specimens from a second surface shall be at least the greater of $1\frac{1}{2}$ in. [40 mm] or 2*t*.

6.5 *Number of Tests:*

6.5.1 Up to 200 like forgings, each with a heat-treated weight of less than 1000 lb [510 kg] when heat treated in a single batch furnace charge, shall have one tension test taken in accordance with 6.4.1 or 6.4.2 to represent each heat. In addition, for hollow or bored forgings, one bend or flattening test shall be taken in accordance with 6.3.

6.5.2 Like forgings, weighing less than 1000 lb [450 kg] each when heat treated in a continuous furnace, shall have one tensile test taken to represent each heat and not more than 200 forgings in any continuous period up to 4 h duration. In addition, bored or hollow forgings shall have one bend or flattening test taken per heat per 200 forgings in any continuous period up to 4 h duration in accordance with 6.3.

6.5.3 For heat-treated forgings weighing 1000 lb [450 kg] or more, one tension test shall be taken in accordance with 6.4.1 or 6.4.2 to represent each heat and not more than ten forgings in a heat-treat lot. In addition, hollow or bored forgings shall have one bend or flattening test, taken in accordance with 6.3, to represent each ten or fewer forgings for the same heat and heat-treatment lot.

6.6 *Hardness Testing:*

6.6.1 Forgings under 1000 lb [450 kgm] in weight, heat treated in a batch lot of up to 200 pieces (6.5.1) or in a continuous furnace run covering up to 200 pieces in up to four hours production (6.5.2) shall be subject to a uniformity check by Brinell hardness testing, or an equivalent method. For this purpose, 10% of the furnace production shall be sampled and shall meet the minimum hardness specified in Table 2 for the type and shall also be within 20 Brinell points of the hardness of the forging from which the tensile test was taken.

6.6.2 In the event that the test sample does not meet these criteria, the remainder of that production group shall be hardness tested and all of those forgings that fall outside these limits shall be retempered or reheat-treated at the manufacturer's option and retested.

7. Magnetic Particle Examination

7.1 All quenched and tempered forgings shall be subject to magnetic particle examination after heat treatment. The methods used shall be in accordance with Test Method A 275/A 275M.

7.2 Only direct current or rectified alternating (full or half wave) current shall be used as the electric power source for any of the magnetizing methods.

7.3 The forgings shall be free from linear indications indicative of cracks. In case of doubt as to the type of condition giving rise to linear magnetic particle indications, they may be inspected for Type II indications referenced in Reference Photographs E 433 when inspected by the liquid penetrant method in accordance with Practice E 165. Alternatively, some other suitable method for classifying the indications may be used as agreed upon between the manufacturer and the purchaser.

8. Workmanship

8.1 If the thickness of a portion of the wall of a forging is less than that specified, the forgings may be accepted by the purchaser, provided that such irregularity will not require lowering the allowable working pressure below that for which the forging was designed.

9. Repair Welding

9.1 Repair welding shall be permitted when mutually agreed upon between the purchaser and the manufacturer and shall be performed in accordance with all the requirements of the applicable code or rules of construction.

10. Keywords

10.1 alloy steel forgings; carbon steel forgings; gas bottles; pressure vessels; thin wall

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %			
	Grade A	Grade B	Grade C	Grade D
Carbon	0.30 max	0.35 max	0.48 max	0.40–0.50
Manganese	1.00 max	1.35 max	1.65 max	1.40–1.80
Phosphorus, max	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025
Silicon	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35
Nickel	—	—	—	—
Chromium	—	—	—	—
Molybdenum	—	—	—	0.17–0.27

	Grade E Classes 55, 65, 70	Grade F Classes 55, 65, 70	Grade G Classes 55, 65, 70	Grade H Classes 55, 65, 70	Grade J Classes 55, 65, 70, 110
Carbon	0.25–0.35	0.30–0.40	0.25–0.35	0.30–0.40	0.35–0.50
Manganese	0.40–0.90	0.70–1.00	0.70–1.00	0.75–1.05	0.75–1.05
Phosphorus, max	0.025	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025
Silicon	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35
Nickel	—	—	—	—	—
Chromium	0.80–1.15	0.80–1.15	0.40–0.65	0.40–0.65	0.80–1.15
Molybdenum	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25

	Grade K	Grade L	Grade M Classes A and B
Carbon	0.18 max	0.38–0.43	0.23 max
Manganese	0.10–0.40	0.60–0.80	0.20–0.40
Phosphorus, max	0.025 max	0.025	0.020
Sulfur, max	0.025 max	0.025	0.020
Silicon	0.15–0.35	0.15–0.35	0.30 max
Nickel	2.0–3.3	1.65–2.00	2.8–3.9
Chromium	1.00–1.80	0.70–0.90	1.50–2.00
Molybdenum	0.20–0.60	0.20–0.30	0.40–0.60
Vanadium			0.08 max

TABLE 2
MECHANICAL REQUIREMENTS

Type	Tensile Strength, ksi [MPa]	Yield Strength (0.2% Offset), ksi [MPa], min	Elongation in 2 in. [50 mm], min, %	Hardness, HB, min[A]
Grade A	60–85 [415–585]	35 [240]	20	121
Grade B	75–100 [515–690]	45 [310]	18	156
Grade C	90–115 [620–795]	55 [380]	15	187
Grade D	105–130 [725–895]	65 [450]	15	217
Grades E, F, G, H, J (Class 55)	85–110 [545–760]	55 [380]	20	179
Grades E, F, G, H, J (Class 65)	105–130 [725–895]	65 [450]	19	217
Grades E, F, G, H, J (Class 70)	120–145 [825–1000]	70 [485]	18	248
Grade J (Class 110)	135–160 [930–1100]	110 [760]	15	277
Grade K	100–125 [690–860]	80 [550]	20	207
Grade L	155–180 [1070–1240]	135 [930]	12	311
Grade M (Class A)	105–130 [725–895]	85 [585]	18	217
Grade M (Class B)	120–145 [825–1000]	100 [690]	16	248

[A] When required by 6.6.

TABLE 3
DISTANCE BETWEEN PLATES FOR FLATTENING TESTS[A]

Type	Distance Between Plates, min, in. [mm]
Grade A	0.50 *D*
Grade B	0.6 *D*
Grade C	0.65 *D*
Grade D	0.7 *D*
Grades E, F, G, H, J (Class 55)	0.7 *D*
Grades E, F, G, H, J (Class 65)	0.8 *D*
Grades E, F, G. H, J (Class 70)	0.8 *D*
Grade J (Class 110)	0.9 *D*
Grade K	0.8 *D*
Grade L	0.9 *D*
Grade M (Class A)	0.7 *D*
Grade M (Class B)	0.8 *D*

[A] *D* = outside diameter.

TABLE 4
MAXIMUM PIN DIAMETERS AND MINIMUM ANGLE FOR BEND TEST

Type	Pin Diameter	Angle, deg
Grade A	2*t*	180
Grade B	2*t*	180
Grade C	3*t*	180
Grade D	4*t*	150
Grades E, F, G, H, J (Class 55)	4*t*	150
Grades E, F, G, H, J (Class 65)	4*t*	150
Grades E, F, G, H, J (Class 70)	4*t*	150
Grade J (Class 110)	6*t*	150
Grade K	4*t*	150
Grade L	6*t*	150
Grade M (Class A)	4*t*	150
Grade M (Class B)	4*t*	150

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser on the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Grain Size

S1.1 When a grain size range is required, it shall be specified in the ordering information and shall be determined by an agreed-upon method for Test Methods E 112.

S1.2 Samples for grain size estimation shall be taken from the tension test specimen location.

S2. Rough Machining

S2.1 Rough machining shall be performed in the sequence and manner as specified.

S3. Impact Testing

S3.1 Charpy V-notch test specimens shall be taken from the same location and in the same orientation as tension test specimens. The number of specimens, minimum energy values, and test temperature(s) shall be as specified.

S4. Fracture Toughness

S4.1 Specific fracture toughness requirements are levied by certain sections of the ASME Boiler and Pressure Vessel Code. Forgings in the permitted types shall comply with the applicable Code sections.

S4.2 The necessary Code references toughness criteria and test temperature data shall be included in the ordering information.

S5. Ultrasonic Examination

S5.1 Ultrasonic examination of forgings shall be carried out in accordance with Practice A 388/A 388M.

S5.2 Acceptance criteria shall be specified and shall be in accordance with the applicable Code or purchaser's specification and shall be included as part of the ordering information.

SPECIFICATION FOR SEAMLESS AUSTENITIC STEEL PIPE FOR HIGH-TEMPERATURE CENTRAL-STATION SERVICE

SA-376/SA-376M

(Identical with ASTM Specification A 376/A 376M-93 except for editorial differences in Table 2, and clarified heat treatment requirements in 5.2.1.) 98

1. Scope

1.1 This specification covers seamless austenitic steel pipe intended for high-temperature central-station service. Among the grades covered are five H grades and two nitrogen grades (304N and 316N) that are specifically intended for high-temperature service.

1.2 Optional supplementary requirements (S1 through S10) are provided. These supplementary requirements specify additional tests that will be made only when stated in the order, together with the number of such tests required.

1.3 Grades TP321 and TP321H have lower strength requirements for nominal wall thicknesses greater than $^{3}/_{8}$in. [9.5 mm].

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalent; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:* 98

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 112 Test Methods for Determining the Average Grain Size

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

2.2 *ASME Boiler and Pressure Vessel Code:*

Section IX Welding Qualifications

3. General Requirements

3.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material to this specification should include the following, as required to describe the desired material adequately:

4.1.1 Quantity (feet, centimetres, or number of lengths),

4.1.2 Name of material (seamless austenitic steel pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (nominal size, or outside diameter and schedule number or average wall thickness),

4.1.5 Lengths (specific or random), (Permissible Variations in Length Section of Specification A 530/A 530M),

4.1.6 End finish (Ends Section of Specification A 530/A 530M),

4.1.7 Optional requirements (Section 8) (see Hydrostatic Test Requirements Section and the Permissible Variation in Weight for Seamless Pipe Section for weighing individual lengths, of Specification A 530/A 530M), (see 9.6, repairing by welding; 12.2, die stamping),

4.1.8 Test report required (Certification Section of Specification A 530/A 530M),

4.1.9 Specification designation, and

4.1.10 Special requirements or any supplementary requirements selected or both.

5. Materials and Manufacture

5.1 *Manufacture* — At the manufacturer's option, pipe may be either hot finished or cold finished, with a suitable finishing treatment, where necessary.

5.2 *Heat Treatment:*

5.2.1 For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. All pipe shall be furnished in the heat-treated condition unless the order specifically states that no final heat treatment shall be applied. When the order is furnished without final heat treatment, each pipe shall be stenciled "HT-O."

5.2.2 *Grades TP304, TP304N, TP304LN, TP316, TP316N, TP316LN, TP321, TP347, TP348, 16-8-2H, S31725, and S31726* — Unless otherwise stated in the order, heat treatment shall consist of heating to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means.

5.2.2.1 The purchaser may specify controlled structural or special service characteristics which shall be used as a guide for the most suitable heat treatment. If the final heat treatment is at a temperature under 1900°F [1040°C], each pipe shall be stenciled with the final heat treatment temperature in degrees Fahrenheit or Celsius after the suffix "HT."

5.2.3 *Grades TP304H, TP316H, TP321H, TP347H, and 16-8-2H* — If cold working is involved in processing, the minimum solution-treating temperature for Grades TP321H and TP347H shall be 2000°F [1100°C], for Grades TP304H and TP316H 1900°F [1040°C] and for Grade 16-8-2H, 1800°F [980°C]. If the material is hot-rolled, the minimum solution-treating temperatures for Grades TP321H and TP347H shall be 1925°F [1050°C], for Grades TP304H and TP316H, 1900°F [1040°C], and for Grade 16-8-2H, 1800°F [980°C].

5.3 A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S9).

5.4 The grain size of TP321H, as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Product Analysis

7.1 At the request of the purchaser, an analysis of one billet from each heat or two pipes from each lot (Note 2) shall be made by the manufacturer. A lot of pipe shall consist of the following:

NPS Designator	Lengths of Pipe in Lot
Under NPS 2	400 or fraction thereof
NPS 2 to NPS 5, incl	200 or fraction thereof
Over NPS 5	100 or fraction thereof

NOTE 2 — A lot shall consist of the number of lengths specified in 7.1 of the same size and wall thickness from any heat or steel.

7.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Table 1.

7.3 If the analysis of one of the tests specified in Section 8 does not conform to the requirements specified in Section 6, an analysis of each billet or pipe from

the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

9. Workmanship, Finish, and Appearance

9.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to assure compliance with 9.2.

9.2 Surface imperfections that penetrate more than $12\frac{1}{2}$% of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

9.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

9.2.2 Repaired in accordance with the repair welding provisions of 9.6.

9.2.3 The section of pipe containing the defect may be cut off within the limits of requirements of length.

9.2.4 Rejected.

9.3 To provide a workmanlike finish and basis for evaluating conformance with 9.2, the pipe manufacturer shall remove by grinding the following:

98 **9.3.1** Mechanical marks, abrasions (Note 3), and pits, any of which imperfections are deeper than $\frac{1}{16}$ in. [1.6 mm].

98 NOTE 3 — Marks and abrasions are defined as cable marks, dinges, guide marks, roll marks, ball scratches, scores, die marks, etc.

9.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 9.1 to be deeper than 5% of the nominal wall thickness.

9.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 9.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

9.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

9.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

9.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

9.7 The finished pipe shall be reasonably straight.

9.8 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that is passivating treatment be applied.

10. Mechanical Tests Required

10.1 *Transverse or Longitudinal Tension Test*—The tension test shall be performed on 1% of the pipe from each lot.

NOTE 4—The term "lot" applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace. When final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge. 98

10.2 *Flattening Test*—For pipe heat treated in a batch type furnace, the flattening test shall be made on 5% of the pipe from each heat-treated lot (Note 4). When heat treated by the continuous process, this test shall be made on a sufficient number of pipe to constitute 5% of the lot (Note 4) but in no case less than two pipes. 98

10.3 *Hydrostatic Test*—Each length of pipe shall be subjected to the hydrostatic test. The results of these tests shall be reported to the purchaser or the purchaser's representative.

10.4 For pipe sizes NPS 24 and over, the purchaser with the agreement of the manufacturer, may complete the hydrostatic test requirement with the system pressure test, which may be lower or higher than the specification test pressure, but in no case shall the test pressure be

lower than the system design pressure. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory marking the letters "NH".

11. Certification

11.1 In addition to the certification required by Specification A 530/A 530M, the certification for pipe furnished to this specification shall identify each length of pipe which is furnished without the manufacturer's completed hydrostatic test, in accordance with 10.4.

12. Product Marking

98 **12.1** In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include the length, hydrostatic test pressure, the symbol "S" if the pipe conforms to the supplementary requirements specified in S1 to S10, the ANSI schedule number, the heat number or manufacturer's number by which the heat can be identified, and the marking requirements of 5.2.

12.2 No steel indentation stamping shall be done without the purchaser's consent.

TABLE 1
CHEMICAL REQUIREMENTS

Grade	UNS Designation	Carbon	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Titanium	Columbium + Tantalum	Tantalum	Nitrogen[F]	Others
TP304	...	0.8 max	2.00	0.040	0.030	0.75	8.00–11.0	18.0–20.0	...	...	...	...	...	...
TP304H	...	0.04–0.10	2.00	0.040	0.030	0.75	8.00–11.0	18.0–20.0	...	...	...	...	...	...
TP304N	...	0.08 max	2.00	0.040	0.030	0.75	8.00–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...
TP304LN	...	0.035 max	2.00	0.040	0.030	0.75	8.00–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...
TP316	...	0.08 max	2.00	0.040	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...
TP316H	...	0.04–0.10	2.00	0.040	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...
TP316N	...	0.08 max	2.00	0.040	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...
TP316LN	...	0.035 max	2.00	0.040	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...
TP321	...	0.08 max	2.00	0.040	0.030	0.75	9.00–13.0	17.0–20.0	[B]	...	...	...	...	...
TP321H	...	0.04–0.10	2.00	0.040	0.030	0.75	9.00–13.0	17.0–20.0	[C]	...	...	...	...	...
TP347	...	0.08 max	2.00	0.040	0.030	0.75	9.00–13.0	17.0–20.0	...	...	[D]	...	...	...
TP347H	...	0.04–0.10	2.00	0.040	0.030	0.75	9.00–13.0	17.0–20.0	...	...	[E]	...	...	...
TP348[A]	...	0.08 max	2.00	0.040	0.030	0.75	9.00–13.0	17.0–20.0	...	...	[D]	0.10	...	...
16-8-2H	...	0.05–0.10	2.00	0.040	0.030	0.75	7.50–9.50	14.5–16.5	1.5–2.0	...	...	...	...	...
...	S31725	0.03 max	2.00	0.040	0.030	0.75	13.5–17.5	18.0–20.0	4.0–5.0	...	...	...	0.10 max	Cu 0.75 max
...	S31726	0.03 max	2.00	0.040	0.030	0.75	13.5–17.5	17.0–20.0	4.0–5.0	...	...	...	0.10–0.20	Cu 0.75 max

[A] This grade is intended for special purpose applications.
[B] The titanium content shall be not less than five times the carbon content and not more than 0.60%.
[C] The titanium content shall be not less than four times the carbon content and not more than 0.60%.
[D] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.00%.
[E] The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.00%.
[F] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

98

TABLE 2
TENSILE REQUIREMENTS

Grade	Tensile[A] strength, min, ksi [MPa]	Yield strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm (or 40) min, %	
			Longitudinal	Transverse
TP304, TP304H, TP304LN, TP316, TP316H, TP316LN, TP347, TP347H, TP348, 16-8-2H, S31725	75 [515]	30 [205]	35	25
TP304N, TP316N, S31726	80 [550]	35 [240]	35	25
TP321, TP321H				
≤3/8"	75 [515]	30 [205]	35	25
>3/8"[B]	70 [480]	25 [170]	35	25

[A] For grade TP304, NPS8 or larger, in schedules 140 and heavier, the required minimum tensile strength shall be 70 ksi [480 MPa].
[B] Prior to the issuance of A 376/A 376M — 88, the tensile and yield strength values were 75 [520] and 30 [210] respectively for nominal wall greater than 3/8 in. [9.5 mm].

SUPPLEMENTARY REQUIREMENTS FOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over in nominal diameter. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Photomicrographs

S5.1 Photomicrographs at 100 diameters may be made from one end of each piece of pipe furnished in sizes 6 in. [152 mm] and larger in the as-furnished condition. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, piece number, and heat. Such photomicrographs are for information only, and shall show the actual metal structure of the pipe as finished.

S6. Ultrasonic Test

S6.1 Each piece of pipe may be ultrasonically tested to determine its soundness throughout the entire length of the pipe. Each piece shall be ultrasonically tested in a circumferential direction in such a manner that the entire piece is scanned by the ultrasonic beam. The calibration standard shall be prepared from a section of pipe which has two notches, one in the inside surface and one in the outside surface. The notches shall be at least $1\frac{1}{2}$ in. [38 mm] long and have a depth of 3% of the wall thickness, or 0.004 in. [0.1 mm], whichever is the greater. Any pipe showing an ultrasonic indication of greater amplitude than the amplitude of the indication from the calibration standard shall be subject to rejection.

S7. Hot Ductility Test for Indicating Weldability

S7.1 A high-temperature ductility test may be made upon each heat of material supplied in heavy-wall pipe sections. An appropriate specimen shall be heated to an initial temperature, cooled 100°F [50°C], then subjected to a tension test, and shall show a minimum reduction of area of 60%. The initial temperature is that temperature 50°F [30°C] below the temperature at which material exhibits zero ductility. Rejection of material shall not be based upon this test.

S8. Retests

S8.1 Upon the purchaser's request, retests shall be made from sections of material removed from any part of the pipe. Failure to meet the requirements stated in this specification shall be cause for rejection.

S9. Stabilization Heat Treatment

S9.1 Subsequent to the solution anneal required in 5.4, Grades TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S10. Intergranular Corrosion Test

S10.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE 5—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S10.2 A stabilization heat treatment in accordance with Supplementary Requirement S9 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, CHROMIUM-MOLYBDENUM

SA-387/SA-387M

(Identical with ASTM Specification A 387/A 387M92$^{\epsilon 1}$.)

1. Scope

1.1 This specification covers chromium-molybdenum alloy steel plates intended primarily for welded boilers and pressure vessels designed for elevated temperature service.

1.2 Plates are available under this specification in several grades having different alloy contents as follows:

Grade	Nominal Chromium Content, %	Nominal Molybdenum Content, %
2	0.50	0.50
12	1.00	0.50
11	1.25	0.50
22, 22L	2.25	1.00
21, 21L	3.00	1.00
5	5.00	0.50
9	9.00	1.00
91	9.00	1.00

1.3 Each grade except Grades 21L, 22L, and 91 is available in two classes of tensile strength levels as defined in Tensile Requirements tables, depending on heat treatment. In the annealed condition all grades are available only as Class 1. Grades 21L and 22L are available only as Class 1. Grade 91 is available only as Class 2.

1.4 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and weight, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M. If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed.

5. Heat Treatment

5.1 Except for Grade 91, all plates shall be thermally treated either by annealing, normalizing-and-tempering, or, when permitted by the purchaser, accelerated cooling from the austenitizing temperature by air blasting or liquid quenching, followed by tempering. Minimum tempering temperatures shall be as follows:

Grade	Temperature, °F [°C]
2, 12, and 11	1150 [620]
22, 22L, 21, 21L, and 9	1250 [675]
5	1300 [705]

5.1.1 Grade 91 plates shall be normalized at 1900 to 2000°F [1040 to 1095°C] and shall be tempered at not less than 1350°F [730°C].

5.2 Grade 5, 9, 21, 21L, 22, 22L, and 91 plates ordered without the heat treatment required by 5.1 shall be furnished in either the stress-relieved or the annealed condition.

5.3 For plates ordered without the heat treatment required by 5.1, heat treatment of the plates to conform to 5.1 and to Tables 1 or 2, as applicable, shall be the responsibility of the purchaser.

6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M for grades other than Grade 11.

7. Metallurgical Structure

7.1 *Austenitic Grain Size* — Grade 2 material shall have a coarse austenitic grain size.

8. Mechanical Requirements

8.1 *Tension Test Requirements:*

8.1.1 The material as represented by the tension test specimens shall conform to the applicable requirements of Table 2 or Table 3, as specified on the order.

8.1.2 Adjustment of the percentage elongation requirements is permitted in accordance with Specification A 20/A 20M for plates up to $\frac{3}{4}$ in. [20 mm] inclusive, in thickness when an 8 in. [200 mm] gage length is used.

9. Marking

9.1 In addition to the marking required in Specification A 20/A 20M, each plate shall be legibly stamped or stenciled, depending upon the ordered thickness, with the letter *A* for annealed, *N* for normalized and tempered, and *Q* for accelerated cooled and tempered, as applicable.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %									
	Grade 2	Grade 12	Grade 11	Grade 22	Grade 22L	Grade 21	Grade 21L	Grade 5	Grade 9	Grade 91
Carbon										
Heat analysis	0.05–0.21	0.05–0.17	0.05–0.17	0.05–0.15 [Note (1)]	0.10 max	0.05–0.15 [Note (1)]	0.10 max	0.15 max	0.15 max	0.08–0.12
Product analysis	0.04–0.21	0.04–0.17	0.04–0.17	0.04–0.15 [Note (1)]	0.12 max	0.04–0.15 [Note (1)]	0.12 max	0.15 max	0.15 max	0.06–0.15
Manganese:										
Heat analysis	0.55–0.80	0.40–0.65	0.40–0.65	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60
Product analysis	0.50–0.88	0.35–0.73	0.35–0.73	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66
Phosphorus, max:										
Heat analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.030	0.020
Product analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.030	0.025
Sulfur, max:										
Heat analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.030	0.030	0.010
Product analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.030	0.030	0.012
Silicon:										
Heat analysis	0.15–0.40	0.15–0.40	0.50–0.80	0.50 max	0.50 max	0.50 max	0.50 max	0.50 max	1.00 max	0.20–0.50
Product analysis	0.13–0.45	0.13–0.45	0.44–0.86	0.50 max	0.50 max	0.50 max	0.50 max	0.55 max	1.05 max	0.18–0.56
Chromium:										
Heat analysis	0.50–0.80	0.80–1.15	1.00–1.50	2.00–2.50	2.00–2.50	2.75–3.25	2.75–3.25	4.00–6.00	8.00–10.00	8.00–9.50
Product analysis	0.46–0.85	0.74–1.21	0.94–1.56	1.88–2.62	1.88–2.62	2.63–3.37	2.63–3.37	3.90–6.10	7.90–10.10	7.90–9.60
Molybdenum:										
Heat analysis	0.45–0.60	0.45–0.60	0.45–0.65	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10	0.45–0.65	0.90–1.10	0.85–1.05
Product analysis	0.40–0.65	0.40–0.65	0.40–0.70	0.85–1.15	0.85–1.15	0.85–1.15	0.85–1.15	0.40–0.70	0.85–1.15	0.80–1.10
Nickel, max:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.40
Product analysis	...	...	...	...	...	...	...	...	...	0.43
Vanadium:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.18–0.25
Product analysis	...	...	...	...	...	...	...	...	...	0.16–0.27
Columbium:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.06–0.10
Product analysis	...	...	...	...	...	...	...	...	...	0.05–0.11
Nitrogen:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.030–0.070
Product analysis	...	...	...	...	...	...	...	...	...	0.025–0.080
Aluminum, max:										
Heat analysis	...	...	...	...	...	...	...	...	...	0.04
Product analysis	...	...	...	...	...	...	...	...	...	0.05

NOTE:
(1) The carbon content for plates over 5 in. [125 mm] in thickness is 0.17 max on product analysis.

TABLE 2
TENSILE REQUIREMENTS FOR CLASS 1 PLATES

	Grades 2 and 12	Grade 11	Grades 22, 21, 5, 9, 21L, 22L
Tensile strength, ksi [MPa]	55 to 80 [380 to 550]	60 to 85 [415 to 585]	60 to 85 [415 to 585]
Yield strength, min, ksi [MPa]	33	35	30
Elongation in 8 in. [200 mm], min, % [Note (1)]	18	19	. . .
Elongation in 2 in. [50 mm], min, % [Note (1)]	22	22	18
Reduction of area, min, %	. . .	. . .	45 [Note (2)] 40 [Note (3)]

NOTES:
(1) See Specification A 20/A 20M, elongation adjustments.
(2) Measured on round test specimens.
(3) Measured on flat specimen.

TABLE 3
TENSILE REQUIREMENTS FOR CLASS 2 PLATES [NOTE (1)]

	Grade 2	Grade 11	Grade 12	Grades 22, 21, 5, 9	Grade 91
Tensile strength, ksi [MPa]	70 to 90 [485 to 620]	75 to 100 [515 to 690]	65 to 85 [450 to 585]	75 to 100 [515 to 690]	85 to 110 [585 to 760]
Yield strength, min, ksi [MPa] (0.2 % offset)	45 [310]	45 [310]	40 [275]	45 [310]	60 [415]
Elongation in 8 in. [200 mm], min, % [Note (2)]	18	18	19	. . .	. . .
Elongation in 2 in. [50 mm], min, % [Note (2)]	22	22	22	18	18
Reduction of area, min, %	. . .	. . .	. . .	45 [Note (3)] 40 [Note (4)]	. . .

NOTES:
(1) Not applicable to annealed material.
(2) See Specification A 20/A 20M, elongation adjustments.
(3) Measured on round test specimens.
(4) Measured on flat specimen.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2 Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following supplementary requirements are suitable for this application.

S60. Restricted Carbon

S60.1 The maximum carbon content of Grade 5 shall be 0.10%.

SPECIFICATION FOR ULTRASONIC EXAMINATION OF HEAVY STEEL FORGINGS

SA-388/SA-388M

(Identical with ASTM Specification A 388/A 388M-94.) 98

1. Scope

1.1 This practice covers the examination procedures for the contact, pulse-echo ultrasonic examination of heavy steel forgings by the straight and angle-beam techniques. The straight beam techniques include utilization of the DGS (Distance Gain-Size) method. See Appendix X3.

1.2 This practice is to be used whenever the inquiry, contract, order, or specification states that forgings are to be subject to ultrasonic examination in accordance with Practice A 388/A 388 M.

1.3 The values stated in either inch-pound or SI units are to be regarded as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 This specification and the applicable material specifications are expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation [SI units], the material shall be furnished to inch-pound units.

1.5 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 469 Specification for Vacuum-Treated Steel Forgings for Generator Rotors

E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments

E 428 Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection

2.2 *ANSI Standard:*

B46.1 Surface Texture

2.3 *Other Document:*

Recommended Practice for Nondestructive Personnel Qualification and Certification SNT-TC-1A, Supplement C — Ultrasonic Testing

3. Ordering Information

3.1 When this practice is to be applied to an inquiry, contract, or order, the purchaser shall so state and shall also furnish the following information:

3.1.1 Method of establishing the sensitivity in accordance with 7.2.2 and 7.3.3 (Vee or rectangular notch),

3.1.1.1 The diameter and test metal distance of the flat-bottom hole and the material of the reference block in accordance with 7.2.2.2,

3.1.2 Quality level for the entire forging or portions thereof in accordance with 10.3, and

3.1.3 Any options in accordance with 6.1, 6.2, and 7.1.10.

4. Apparatus

4.1 An ultrasonic, pulsed, reflection type of instrument shall be used for this examination. The system shall have a minimum capability for examining at frequencies from 1 to 5 MHz. On examining austenitic stainless forgings the system shall have the capabilities for examining at frequencies down to 0.4 MHz.

4.1.1 The ultrasonic instrument shall provide linear presentation (within 5%) for at least 75% of the screen height (sweep line to top of screen). The 5% linearity referred to is descriptive of the screen presentation of amplitude. Instrument linearity shall be verified in accordance with the intent of Practice E 317. Any set of blocks processed in accordance with Practice E 317 or E 428 may be used to establish the specified ±5% instrument linearity.

4.1.2 The electronic apparatus shall contain an attenuator (accurate over its useful range to ±10% (+1 dB) of the amplitude ratio) which will allow measurement of indications beyond the linear range of the instrument.

4.2 *Search Units* having a transducer with a maximum active area of 1 in.^{2} [650 mm^2] with $\frac{3}{4}$ in. [20 mm] minimum to $1\frac{1}{8}$ in. [30 mm] maximum dimensions shall be used for straight-beam scanning (see 7.2); and search units equipped from $\frac{1}{2}$ by 1 in. [13 by 25 mm] to 1 by 1 in. [25 by 25 mm] shall be used for angle-beam scanning (see 7.3).

4.2.1 *Transducers* shall be utilized at their rated frequencies.

4.2.2 Other search units may be used for evaluating and pinpointing indications.

4.3 *Couplants* having good wetting characteristics such as SAE No. 20 or No. 30 motor oil, glycerin, pine oil, or water shall be used. Couplants may not be comparable to one another and the same couplant shall be used for calibration and examination.

4.4 *Reference Blocks* containing flat-bottom holes may be used for calibration of equipment in accordance with 4.1.1 and may be used to establish recording levels for straight beam examination when so specified by the order or contract.

4.5 DGS scales, matched to the ultrasonic test unit and transducer to be utilized, may be used to establish recording levels for straight beam examination, when so specified by the order or contract. The DGS scale range must be selected to include the full thickness cross-section of the forging to be examined. An example of a DGS overlay is found in Appendix X3.

5. Personnel Requirements

5.1 Personnel performing ultrasonic examinations in accordance with this practice shall be qualified and certified in accordance with a written procedure conforming to Recommended Practice SNT-TC-1A or another national standard that is acceptable to both the purchaser and the supplier. **98**

6. Preparation of Forging for Ultrasonic Examination

6.1 Unless otherwise specified in the order or contract, the forging shall be machined to provide cylindrical surfaces for radial examination in the case of round forgings; the ends of the forgings shall be machined perpendicular to the axis of the forging for the axial examination. Faces of disk and rectangular forgings shall be machined flat and parallel to one another.

6.2 The surface roughness of exterior finishes shall not exceed 250 μin. [6 μm] unless otherwise shown on the forging drawing or stated in the order or the contract.

6.3 The surfaces of the forging to be examined shall be free of extraneous material such as loose scale, paint, dirt, etc.

7. Procedure

7.1 *General:*

7.1.1 As far as practicable, subject the entire volume of the forging to ultrasonic examination. Because of radii at change of sections and other local configurations, it may be impossible to examine some sections of a forging.

7.1.2 Perform the ultrasonic examination after heat treatment for mechanical properties (exclusive of stress-relief treatments) but prior to drilling holes, cutting keyways, tapers, grooves, or machining sections to contour. If the configuration of the forging required for the treatment for mechanical properties prohibits a subsequent complete examination of the forging, it shall be permissible to examine prior to treatment for mechanical properties. In such cases, reexamine the forging ultrasonically as completely as possible after heat treatment.

7.1.3 To ensure complete coverage of the forging volume, index the search unit with at least 15% overlap with each pass.

7.1.4 Do not exceed a scanning rate of 6 in./s [150 mm/s].

7.1.5 If possible, scan all sections of forgings in two perpendicular directions.

7.1.6 Scan disk forgings using a straight beam technique from at least one flat face and radially from the circumference whenever practicable.

7.1.7 Scan cylindrical sections and hollow forgings by angle-beam technique. When practicable, also examine the forging in the axial direction.

7.1.8 In addition, examine hollow forgings by angle-beam technique from the outside diameter surface as required in 7.3.1.

7.1.9 In rechecking or reevaluation by manufacturer or purchaser use comparable equipment, search units, frequency, and couplant.

7.1.10 Forgings may be examined either stationary or while rotating in a lathe or on rollers. If not specified by the purchaser, either method may be used at the manufacturer's option.

7.2 *Straight-Beam Examination:*

7.2.1 For straight-beam examination use a nominal $2\frac{1}{4}$ MHz search unit whenever practicable; however, 1 MHz is the preferred frequency for coarse grained austenitic materials and long testing distances. In many instances on examining coarse grained austenitic materials it may be necessary to use a frequency of 0.4 MHz. Other frequencies may be used if desirable for better resolution, penetrability, or detectability of flaws.

7.2.2 Establish the instrument sensitivity by either the reflection, reference-block technique, or DGS method (see Appendix X3 for an explanation of the DGS method).

7.2.2.1 *Back-Reflection Technique (Back-Reflection Calibration Applicable to Forgings with Parallel Entry and Back Surfaces)* — With the attenuator set at an appropriate level, for example 5 to 1 or 14 dB, adjust the instrument controls to obtain a back reflection approximately 75% of the full-screen height from the opposite side of the forging. Scan the forging at the maximum amplification setting of the attenuator (attenuator set at 1 to 1). Carry out the evaluation of discontinuities with the gain control set at the reference level. Recalibration is required for significant changes in section thickness or diameter.

NOTE 1 — High sensitivity levels are not usually employed when inspecting austenitic steel forgings due to attendant high level of "noise" or "hash" caused by coarse grain structure.

7.2.2.2 *Reference-Block Calibration* — The test surface roughness on the calibration standard shall be comparable to but no better than the item to be examined. Adjust the instrument controls to obtain the required signal amplitude from the flat-bottom hole in the specified reference block. Utilize the attenuator in order to set up on amplitudes larger than the vertical linearity of the instrument. In those cases, remove the attenuation prior to scanning the forging.

NOTE 2 — When flat-surfaced reference block calibration is specified, adjust the amplitude of indication from the reference block or blocks to compensate for examination surface curvature (an example is given in Appendix A1).

7.2.2.3 *DGS Calibration* — Prior to use, verify that the DGS overlay matches the transducer size and frequency. Accuracy of the overlay can be verified by reference blocks and procedures outlined in Practice E 317. Overlays are to be serialized to match the ultrasonic transducer and pulse echo testing system that they are to be utilized with.

7.2.2.4 Choose the appropriate DGS scale for the cross-sectional thickness of the forging to be examined. Insert the overlay over the CRT screen, ensuring the DGS scale base line coincides with the sweep line of the CRT screen. Place the probe on the forging, adjust the gain to make the first backwall echo appear clearly on CRT screen. Using the Delay and Sweep control, shift the screen pattern so that the leading edge of the initial pulse is on zero of the DGS scale and the backwall echo is on the DGS scale value corresponding to the thickness of the forging. Adjust the gain so the forging backwall echo matches the height of the DGS reference slope within ± 1 Db. Once adjusted, increase the gain by the Db shown on the DGS scale for the reference slope. Instrument is now calibrated and flaw sizes that can be reliably detected can be directly read from the CRT screen. These flaw sizes are the equivalent flat bottom reflector that can be used as a reference point.

NOTE 3 — The above can be utilized on all solid forgings. Cylindrical hollow forgings, and drilled or bored forgings must be corrected to compensate for attenuation due to the central hole (see Appendix X4).

7.2.3 *Recalibration* — Any change in the search unit, couplant, instrument setting, or scanning speed from that used for calibration shall require recalibration.

Perform a calibration check at least once every 8 h shift. When a loss of 15% or greater in the gain level is indicated, reestablish the required calibration and reexamine all of the material examined in the preceding calibration period. When an increase of 15% or greater in the gain level is indicated, reevaluate all recorded indications.

7.2.4 During the examination of the forging, monitor the back reflection for any significant reduction in amplitude. Reduction in back-reflection amplitude may indicate not only the presence of a discontinuity but also poor coupling of the search unit with the surface of the forging, nonparallel back-reflection surface, or local variations of attenuation in the forging. Recheck any areas causing loss of back reflection.

7.3 *Angle-Beam Examination — Rings and Hollow Forgings:*

7.3.1 Perform the examination from the circumference of rings and hollow forgings that have an axial length greater than 2 in. [50 mm] and an outside to inside diameter ratio of less than 2.0 to 1.

7.3.2 Use a 1 MHz, 45° angle-beam search unit unless thickness, OD/ID ratio, or other geometric configuration results in failure to achieve calibration. Other frequencies may be used if desirable for better resolution, penetrability, or detectability of flaws. For angle-beam inspection of hollow forgings up to 2.0 to 1 ratio, provide the transducer with a wedge or shoe that will result in the beam mode and angle required by the size and shape of the cross section under examination.

7.3.3 Calibrate the instrument for the angle-beam examination to obtain an indication amplitude of approximately 75% full-screen height from a rectangular or a 60° V-notch on inside diameter (ID) in the axial direction and parallel to the axis of the forging. A separate calibration standard may be used; however, it shall have the same nominal composition, heat treatment, and thickness as the forging it represents. The test surface finish on the calibration standard shall be comparable but no better than the item to be examined. Where a group of identical forgings is made, one of these forgings may be used as the separate calibration standard. Cut the ID notch depth to 3% maximum of the thickness or $\frac{1}{4}$ in. [6 mm], whichever is smaller, and its length approximately 1 in. [25 mm]. Thickness is defined as the thickness of the forging to be examined at the time of examination. At the same instrument setting, obtain a reflection from a similar OD notch. Draw a line through the peaks of the first reflections obtained from the ID and OD notches. This shall be the amplitude reference line. It is preferable to have the notches in excess metal or test metal when possible. When the OD notch cannot be detected when examining the OD surface, perform the examination when practicable (some ID's may be too small to permit examination), as indicated above from both the OD and ID surfaces. Utilize the ID notch when inspecting from the OD, and the OD notch when inspecting from the ID. Curve wedges or shoes may be used when necessary and practicable.

7.3.4 Perform the examination by scanning over the entire surface area circumferentially in both the clockwise and counter-clockwise directions from the OD surface. Examine forgings, which cannot be examined axially using a straight beam, in both axial directions with an angle-beam search unit. For axial scanning, use rectangular or 60° V-notches on the ID and OD for the calibration. These notches shall be perpendicular to the axis of the forging and the same dimensions as the axial notch.

8. Recording

8.1 *Straight-Beam Examination* — Record the following indications as information for the purchaser. These recordable indications do not constitute a rejectable condition unless negotiated as such in the purchase order.

8.1.1 In the back-reflection technique, individual indications equal to or exceeding 10% of the back reflection from an adjacent area free from indications; in the reference-block or DGS technique, indications equal to or exceeding 100% of the reference amplitude.

8.1.2 An indication that is continuous on the same plane regardless of amplitude, and found over an area larger than twice the diameter of the search unit. The extent of such an indication shall be accurately measured along with variations in amplitudes of reflections.

8.1.2.1 Planar indications shall be considered continuous over a plane if they have a major axis greater than 1 in. [25 mm]. In recording these indications corrections must be made for beam divergence at the estimated flaw depth.

8.1.3 In the back-reflection technique, discontinuity indications equal to or exceeding 5% of the back reflection. In the reference-block technique, indications equal to or exceeding 50% of the reference amplitude providing that they travel, are continuous, or appear as clusters.

8.1.3.1 Traveling indications are herein defined as indications whose leading edge moves a distance equivalent to 1 in. [25 mm] or more of metal depth with movement of the search unit over the surface of the forging.

8.1.3.2 A cluster of indications is defined as five or more indications located in a volume representing a 2 in. [50 mm] or smaller cube in the forging.

8.1.4 Reduction in back reflection exceeding 20% of the original measured in increments of 10%.

8.1.5 Amplitudes of recordable indications in increments of 10%.

8.2 *Angle-Beam Examination* — Record discontinuity indications equal to or exceeding 50% of the indication from the reference line. When an amplitude reference line cannot be generated, record discontinuity indications equal to or exceeding 50% of the reference notch. These recordable indications do not constitute a rejectable condition unless negotiated as such in the purchase order.

9. Report

9.1 Report the following information:

9.1.1 All recordable indications (see Section 8).

9.1.2 For the purpose of reporting the locations of recordable indications, a sketch shall be prepared showing the physical outline of the forging including dimensions of all areas not inspected due to geometric configuration, the purchaser's drawing number, the purchaser's order number, and the manufacturer's serial number, and the axial, radial, and circumferential distribution of recordable ultrasonic indications.

9.1.3 The specification to which the examination was performed as well as the frequency used, method of setting sensitivity, type of instrument, surface finish, couplant, and search unit employed.

9.1.4 The inspector's signature and date examination performed.

10. Quality Levels

10.1 This practice is intended for application to forgings, with a wide variety of sizes, shapes, compositions, melting processes, and applications. It is, therefore, impracticable to specify an ultrasonic quality level which would be universally applicable to such a diversity of products. Ultrasonic acceptance or rejection criteria for individual forgings should be based on a realistic appraisal of service requirements and the quality that can normally be obtained in the production of the particular type forging.

10.2 Heavy austenitic stainless steel forgings are more difficult to penetrate ultrasonically than similar carbon or low-alloy steel forgings. The degree of attenuation normally increases with section size; and the noise level, generally or in isolated areas, may become too great to permit detection of discrete indications. In most instances, this attenuation results from inherent coarse grained microstructure of these austenitic alloys. For these reasons, the methods and standards employed for ultrasonically examining carbon and low-alloy steel forgings may not be applicable to heavy austenitic steel forgings. In general, only straight beam inspecting using a back-reflection reference standard is used. Because of attenuation, use of flat-bottom hole reference standards or angle-beam examination of these grades is normally impracticable.

10.3 Acceptance quality levels shall be established between purchaser and manufacturer on the basis of one or more of the following criteria.

10.3.1 *Straight-Beam Examination:*

10.3.1.1 No indications larger than some percentage of the reference back reflection.

10.3.1.2 No indications equal to or larger than the indication received from the flat-bottom hole in a specific reference block or blocks.

10.3.1.3 No areas showing loss of back reflection larger than some percentage of the reference back reflection.

10.3.1.4 No indications per 10.3.1.1 or 10.3.1.2 coupled with some loss of resultant back reflection per 10.3.1.3.

10.3.1.5 No indications exceeding the reference level specified in the DGS method.

10.3.2 *Angle-Beam Examination* — No indications exceeding a stated percentage of the reflection from a reference notch or of the amplitude reference line.

10.4 Intelligent application of ultrasonic quality levels involves an understanding of the effects of many parameters on examination results.

APPENDICES

(Nonmandatory Information)

X1. TYPICAL TUNING LEVEL COMPENSATION FOR THE EFFECTS OF FORGING CURVATURE

X1.1 The curve (Fig. X1.1) was determined for the following test conditions:

Material	nickel-molybdenum-vanadium alloy steel (Specification A 469, Class 4)
Instrument	Type UR Reflectoscope
Search unit	$1\frac{1}{8}$ in. [30 mm] diameter quartz
Frequency	$2\frac{1}{4}$ MHz
Reference block	ASTM No. 3-0600 (aluminum)
Reflection area of reference curve	0.010 in.^{2} [6.5 mm^2] in nickel-molybdenum-vanadium alloy steel
Surface finish	250 μin. [6μm], max, roughness

X1.2 To utilize curve, adjust reflectoscope sensitivity to obtain indicated ultrasonic response on ASTM No. 3-0600 reference block for each diameter as shown. A response of 1 in. [25 mm] sweep-to-peak is used for flat surfaces. Use attenuator to obtain desired amplitude, but do testing at 1 to 1 setting.

X2. INDICATION AMPLITUDE COMPENSATION FOR TEST DISTANCE VARIATIONS

X2.1 The curve (Fig. X2.1) has been determined for the following test conditions:

Material	nickel-molybdenum-vanadium alloy steel (Specification A 469, Class 4)
Instrument	Type UR Reflectoscope
Search unit	$1\frac{1}{8}$ in. [30 mm] diameter quartz
Frequency	$2\frac{1}{4}$ MHz
Couplant	No. 20 oil
Reference block	ASTM No. 3-0600 (aluminum)
Reflection area of reference curve	0.010 in.^{2} [6.5 mm^2] in nickel-molybdenum-vanadium alloy steel
Surface finish	250 μin. [6μm], max, roughness

X2.2 To utilize curve, establish amplitude from ASTM reference block to coincide with values from Appendix X1.

X3. BACKGROUND INFORMATION ON THE DGS METHODS

X3.1 The DGS method was developed to determine flaw sizes by comparison to a back wall echo produced on the part to be ultrasonic tested. The derivation of DGS curves is extensively covered and can be found in standard texts on ultrasonic testing, and will not be covered here. The distance or thickness of the forging (*A*) to be tested, as noted on the overlay, must be accurately defined on the CRT screen. The back reflection (*B*) of the part must be established and suitable gain added. Flaw echo indications that appear can be sized via the flaw size curves (*C*) on the overlay. Item (*D*) depicts the transducers that the overlay works in conjunction with and (*E*) depicts the series of curves that the overlay scales are matched to.

X4. COMPENSATION FOR CENTER HOLE ATTENUATION ON CYLINDRICAL BORED OR HOLLOW FORGINGS UTILIZING THE DGS METHOD

98

X4.1 The hole in a cylindrical bored forging causes sound scatter. In these cases, a correction is required which depends on the wall thickness and bore diameter.

X4.1.1 Determine the correction value in dB from the Nomogram (Fig. X3.1).

X4.1.2 Proceed as described in Section 7.2.2.3.

X4.1.3 With the GAIN-dB control, reduce the flaw detector gain by the correction value determined as per the Nomogram (Fig. X4.1). Thus, the flaw detector gain is accurately adjusted.

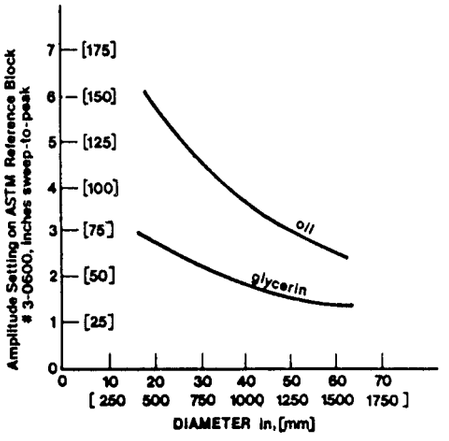


FIG. X1.1 TYPICAL COMPENSATION CURVE FOR EFFECTS OF FORGING CURVATURE

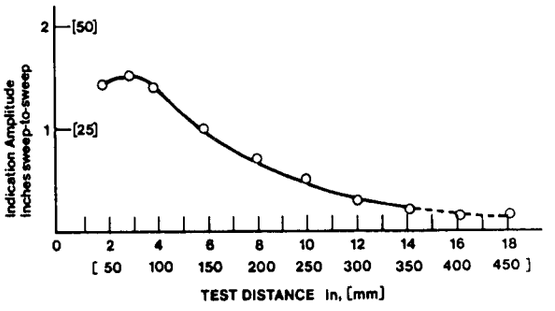


FIG. X2.1 TYPICAL DISTANCE-AMPLITUDE CORRECTION CURVE

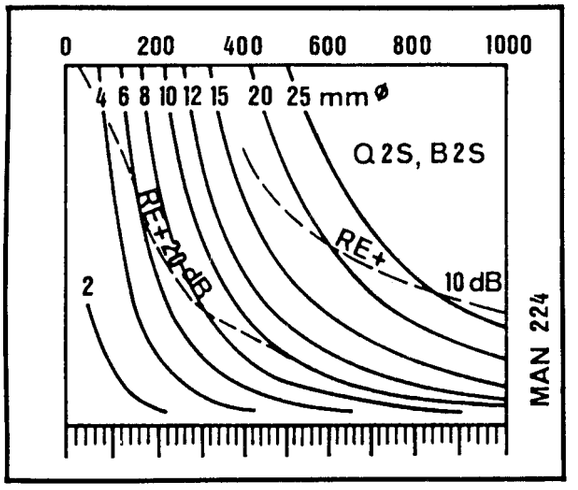
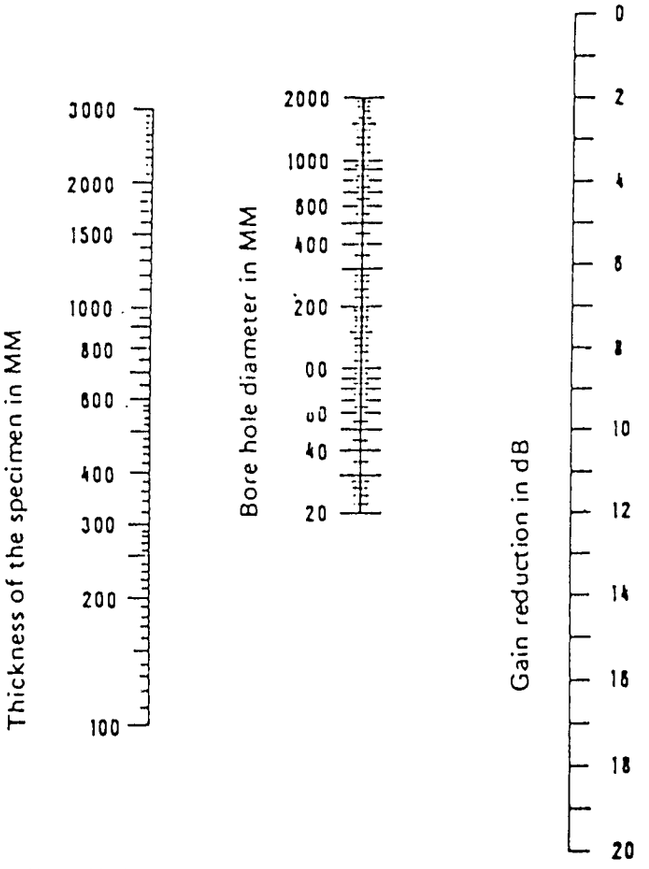


FIG. X3.1 EXAMPLE OF DGS OVERLAY



NOTE—Metric units are presented in this figure to be consistent with DGS scales presently available. Conversion to English units would also be acceptable.

FIG. X4.1 THE INFLUENCE OF A CENTRAL BORE ON THE BACKWALL ECHO AMPLITUDE OF CYLINDRICAL OR PLANE PARALLEL FORGINGS

SPECIFICATION FOR FERRITIC DUCTILE IRON PRESSURE-RETAINING CASTINGS FOR USE AT ELEVATED TEMPERATURES

SA-395

(Identical with ASTM Specification A 395-88 (Reapproved 1993)$^{\epsilon 1}$.

1. Scope

1.1 This specification covers ductile iron castings for pressure-retaining parts for use at elevated temperatures (Note 1).

1.2 Valves, flanges, pipe fittings, pumps, and other piping components are generally manufactured in advance and supplied from stock by the manufacturer, jobber, or dealer.

1.3 For supplemental casting requirements Specification A 834 may be utilized.

1.4 The values stated within this specification are in inch/pound units. A separate Specification A 395M is the metric companion to this specification. The text in both is identical.

NOTE 1 — For service other than as specified in this section, reference should be made to Specification A 536 for Ductile Iron Castings.

2. Referenced Documents

2.1 *ASTM Standards:*

A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 395M Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures (Metric)

A 536 Specification for Ductile Iron Castings

A 732/A 732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures

A 834 Specification for Common Requirements for Iron Castings for General Industrial Use

E 8 Test Methods of Tension Testing of Metallic Materials

E 10 Test Method for Brinell Hardness of Metallic Materials

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron

E 59 Test Method of Sampling Steel and Iron for Determination of Chemical Composition

E 186 Reference Radiographs for Heavy-Walled (2 to $4\frac{1}{2}$-in. (51 to 114-mm)) Steel Castings

E 280 Reference Radiographs for Heavy-Walled ($4\frac{1}{2}$ to 12-in. (114 to 305-mm)) Steel Castings

E 446 Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness

E 689 Reference Radiographs for Ductile Iron Castings

2.2 *Manufacturer's Standardization Society of the Valve and Fittings Industry Standard:*

SP 25 (1964 edition) Standard Marking Systems for Valves, Flanges, Pipe Fittings, and Unions

3. Ordering Information

3.1 Orders for material under this specification shall include the following applicable information:

3.1.1 Drawing, catalog number or part identifications,

3.1.2 Quantity (weight or number of pieces),

3.1.3 ASTM designation and year of issue,

3.1.4 Heat treating requirements (see 4.2.1),

3.1.5 Pressure test requirements (see 6.4.2),

3.1.6 Test samples from castings (see 9.1.1 and 10.1.1),

3.1.7 Test coupons size (see 9.2),

3.1.8 Metallographic option (see 10.1.1),

3.1.9 Place of inspection (see 14.1),

3.1.10 Certification requirements (see 15.1),

3.1.11 Identification marking (see 16.2), and

3.1.12 Supplemental Requirements (see 1.3 and S1).

4. Materials and Manufacture

4.1 The melting method and the nodularizing practice shall be optional with the foundry.

4.2 Except as provided in 4.2.1, all castings shall be given a ferritizing heat treatment that produces essentially a ferritic structure that contains no massive carbides.

4.2.1 When specified in the purchase order, castings may be provided in an as cast condition provided they comply with the requirements of 6.1 and 6.2.1.

4.2.2 Castings supplied in accordance with 4.2.1 may be stress relieved by agreement between the manufacturer and purchaser.

5. Chemical Requirements

5.1 The casting shall conform to the following requirements for chemical composition (Note 2):

Total carbon, min,%	3.00
Silicon, max,%	2.50
Phosphorus, max,%	0.08

5.1.1 The chemical analysis for total carbon shall be made on chilled cast pencil type specimens or from thin wafers approximately $^{1}/_{32}$ in. thick cut from test coupons. Drillings are not reliable because of the probable loss of graphite.

5.1.2 For each reduction of 0.01% below the maximum specified phosphorus content, an increase of 0.08% silicon above the specified maximum will be permitted up to a maximum of 2.75%.

NOTE 2 — Silicon contents above 2.75%, or phosphorus contents above 0.08% have a tendency to lower the impact resistance of the material. If the carbon content is below 3.00%, excess cementite may form during cooling and if this is not removed during heat treatment, the impact resistance of the material may be lowered.

6. Requirements

6.1 *Tensile:* The ductile iron as represented by the test specimens shall conform to the following requirements for tensile properties:

Tensile strength, min, MPa	60 000 psi
Yield strength, min, MPa	40 000 psi
Elongation in% min,%	18

6.2 *Hardness:*

6.2.1 The hardness of the castings and test specimens shall be within the following limits:

HB, 3000 kgf load	143-187

6.3 *Microstructure:*

6.3.1 The microstructure of the separately cast test coupon or the casting shall be essentially ferritic and contain no massive carbides, and have a minimum of 90% Type I and Type II Graphite as in Fig. 7 or Plate I of Test Method A 247.

6.4 *Pressure Test Requirements:*

6.4.1 Each pressure retaining casting shall be tested after machining to the test pressure specified by the applicable standard of ANSI, ASME Boiler and Pressure Vessel Code, or other pertinent code, and shall show no leaks.

6.4.2 Castings ordered under this specification not covered by ANSI standards and ASME Pressure Vessel Code, and castings for special service applications, shall be tested to such pressures as may be agreed upon by the manufacturer and the purchaser.

6.4.3 It is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work or machining has been performed on the casting. Castings ordered in the rough state for final machining by the purchaser may be tested hydrostatically prior to shipment by the manufacturer at pressures to be agreed upon with the purchaser. However, the foundry is responsible for the satisfactory performance of the castings under the final hydrostatic test.

7. Workmanship and Finish

7.1 The surface of the casting shall be examined visually and shall be free from adhering sand, scale, cracks, and hot tears. Any other surface discontinuities shall meet visual acceptance standards specified in the order.

8. Repair

8.1 Castings for valves, flanges, pipe fittings, pumps, and other piping components ordered under applicable ANSI standards shall not be repaired by plugging, welding, brazing, or impregnation.

8.2 Castings not covered in 8.1 which leak on hydrostatic tests may be repaired by plugging, provided the following requirements are met:

8.2.1 No welding or brazing is permitted.

8.2.2 The diameter of the plug shall not exceed the diameter of a standard 2 in. pipe plug.

8.2.3 The plugs, where practical, shall conform in all dimensions to the standard ISO $^{3}/_{8}$ plugs. In addition, they shall have full thread engagement corresponding to the thickness in the repaired section. Where a tapered plug is impractical because of the excess wall thickness in terms of plug diameter and coincident thread engagement, other types of plugs may be used provided both full engagement and effective sealing against pressure are obtained. Where possible, the ends of the plug should be ground smooth after installation to conform to the inside and outside contours of the wall of the pressure vessel or pressure part.

8.2.4 The material from which the plug is manufactured shall conform in all respects to the materials specifications which apply to the pressure vessel or pressure part.

8.2.5 The area adjacent to the drilled hole shall be examined by radiography, and shall meet the Level 3 acceptance requirements of Reference Radiographs E 689 and supporting Reference Radiographs E 446, E 186, or E 280 as applicable and defined in accordance with Reference Radiographs E 689.

8.2.6 The thickness of any repaired section in relation to the size of the plug used shall not be less than that given in Table 1.

8.2.7 The minimum radius of repaired sections of cylinders or cones in relation to the size of plug used shall not be less than that given in Table 2.

8.2.8 A repaired area may consist of a maximum of three plugs with a spacing such that the ligaments between adjacent plugs shall not be less than listed in Table 3. Other defective areas may also be repaired by plugging provided the minimum ligament between plugs in adjacent areas is not less than twice the distance from the nearest plug, the values for which are listed in Table 3.

8.3 Surface imperfections in castings other than valves, flanges, pipe fittings, pumps, and other piping components may be repaired by plugging provided the depth of the plug is not greater than 20% of the thickness of the casting section and the diameter of the plug is not greater than its length. Repair of surface defects may not be done on pressure containing portions of castings. The plug need not be threaded. The conditions of 8.2.1 and 8.2.4 shall also be satisfied.

9. Test Coupon

9.1 The separately cast test coupons from which the tension test specimen is machined shall be cast to the size and shape shown in Fig. 1, Fig. 2, or Fig. 4. Sectioning procedure for removing test specimens from Y-blocks is shown in Fig. 3.

9.1.1 Test samples may be removed from castings at locations designated on a drawing or as agreed to by manufacturer and purchaser.

9.1.2 Test bars removed from castings shall conform to Fig. 5. The testing diameter shall be $^{1}/_{2}$ in. if possible. Smaller diameters shall be utilized if necessary.

9.2 The test coupon size shall be as mutually agreed upon between the manufacturer and purchaser. In the absence of agreement, it shall be the option of the manufacturer.

9.3 The test coupons shall be cast in molds made of suitable core sand having a minimum wall thickness of $1^{1}/_{2}$ in. for the $^{1}/_{2}$ in., 1 in. sizes, and 3 in. for the 3 in. size. The coupons shall be left in the mold until they have changed to a black color (approximately 900°F or less). The keel block as shown in Fig. 1 or the modified keel block produced from the mold shown in Fig. 4 may be substituted for the 1 in. block shown in Fig. 2.

9.4 When investment castings are made to this specification, the manufacturer may use test specimens cast to size incorporated in the mold with the castings or separately cast to size using the same type of mold and the same thermal conditions that are used to produce

the castings. These test specimens shall be made to the dimensions shown in Fig. 1 of Specification A 732 or Figs. 5 and 6 of Test Methods and Definitions A 370.

9.5 Separately cast test coupons shall be poured immediately after the castings and shall represent the metal treated with the nodularizing agent, and be identified with the castings they represent.

9.6 The manufacturer shall cast a sufficient number of test coupons to provide for each ferritizing anneal. The test coupons shall be heat treated with the castings they represent. Sectioning of the test coupons prior to heat treating is not permitted.

9.7 The metallographic examination shall be made on a test lug from the recommended test coupon shown in Fig. 6 or from a casting. The test coupon shall represent the metal treated with the nodularizing agent.

10. Number of Tests and Retests

10.1 One tension test shall be made from sections cut from the test coupons (Fig. 3) for each ladle treated with the nodularizing agent.

10.1.1 Unless otherwise stated in the contract or order for castings, a metallographic examination may be substituted for the tension test when separately cast test coupons are used. When the microstructure option is used, a minimum of one tension test is required from each day's melt and for each heat treatment (see 10.2).

10.2 If any tension test specimen shows obvious defects, another from the same coupon, or from another coupon representing the same metal and the same anneal charge, may be tested. If an apparently sound test specimen fails to conform to this specification, castings may be re-annealed and two retests made. If either retest fails to conform to this specification, the castings they represent shall be rejected.

11. Tension Test Specimen Preparation

11.1 The standard machined ½ in. round tension test specimen with 2 in. gauge length as shown in Fig. 5 shall be used except where the ½ in. Y-block test coupon is required. In this case, either of the small size specimens, 0.375 or 0.250 in. round as shown in Fig. 5 shall be used.

12. Test Methods

12.1 Chemical analysis shall be made in accordance with the following methods: Test Methods E 59 or E 30.

12.2 The chemical composition may also be determined by spectrographic methods but should a dispute arise concerning the chemical composition, the methods specified in 12.1 shall be used as the umpire methods.

12.3 The yield strength shall be determined in accordance with Test Methods E 8 using one of the following methods:

12.3.1 The 0.2% off-set method, or

12.3.2 Extension under load method where the yield strength may be determined as the stress producing an elongation under load of 0.375%; that is, 0.0075 in. in a gauge length of 2 in.

12.4 The hardness of the ductile iron as represented by the test specimens and castings shall be determined in accordance with Test Method E 10.

12.5 The percentage of each graphite type shall be determined by manual counting, semi-automatic or automatic image analysis methods. The sum of all graphite types shall total to 100%.

13. Records

13.1 Records of the chemical composition, mechanical properties, and metallographic examination, when applicable, shall be systematically made and maintained.

14. Inspection

14.1 Unless otherwise specified in the contract or purchase order, the manufacturer shall be responsible for carrying out all the tests and inspection required by this specification.

14.2 The inspector representing the purchaser shall have entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Unless otherwise specified, all tests and inspection shall be made at the place of manufacture or by an approved independent laboratory prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

15. Certification

15.1 When agreed upon in writing by the purchaser and the supplier, a certification shall be made on the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the supplier accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

16. Product Marking

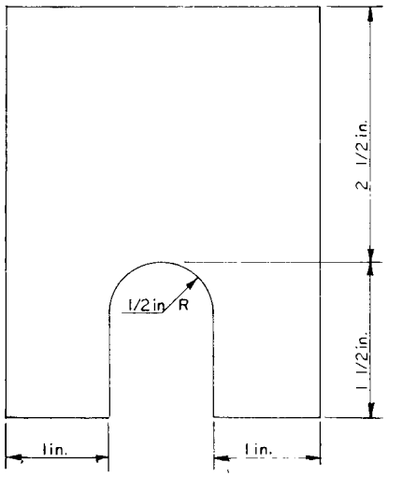
16.1 Casting for valves, flanges, pipe fittings, and unions shall be marked for material identification in accordance with paragraph 9.6 of the Standard Marking System for Valves, Flanges, Pipe Fittings, and Unions, SP-25.

16.2 Castings other than valves, flanges, pipe fittings, and unions shall be identified subject to agreement by the manufacturer and the purchaser.

16.3 Marking shall be in such a position as not to injure the usefulness of the castings.

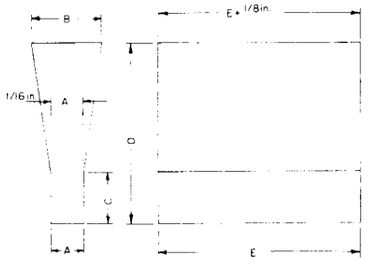
17. Keywords

17.1 casting; ductile iron; mechanical properties; pressure-retaining; pressure test; tensile strength; tension testing; yield strength



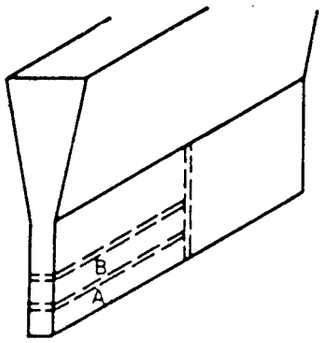
NOTE—The length of the keel block shall be 6 in.

FIG. 1 KEEL BLOCK FOR TEST COUPONS

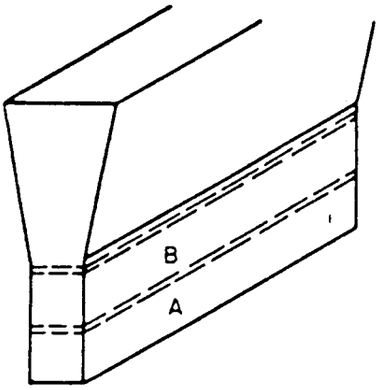


Dimensions	"Y" Block Size		
	For Castings of Thickness Less Than ½ in.	For Castings of Thickness ½ in. to 1½ in.	For Castings of Thickness of 1½ in. and Over
	in.	in.	in
A	½	1	3
B	1⅝	2⅛	5
C	2	3	4
D	4	6	8
E	7 approx	7 approx	7 approx

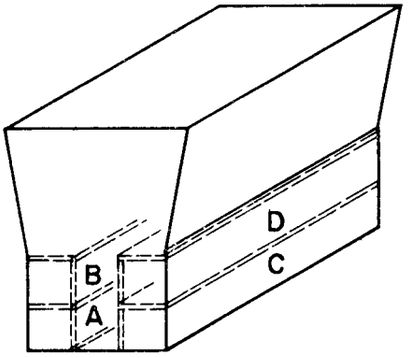
FIG. 2 Y-BLOCKS FOR TEST COUPONS



(*a*) *½-in. Y-Block*—Two blanks for 0.252-in. diameter tension test specimens.



(*b*) *1-in. Y-Block*—Two blanks for 0.50-in. diameter tension test specimens.



(*c*) *3-in. Y-Block*—Two blanks for 0.50-in. diameter tension test specimens.

FIG. 3 SECTIONING PROCEDURE FOR Y-BLOCKS

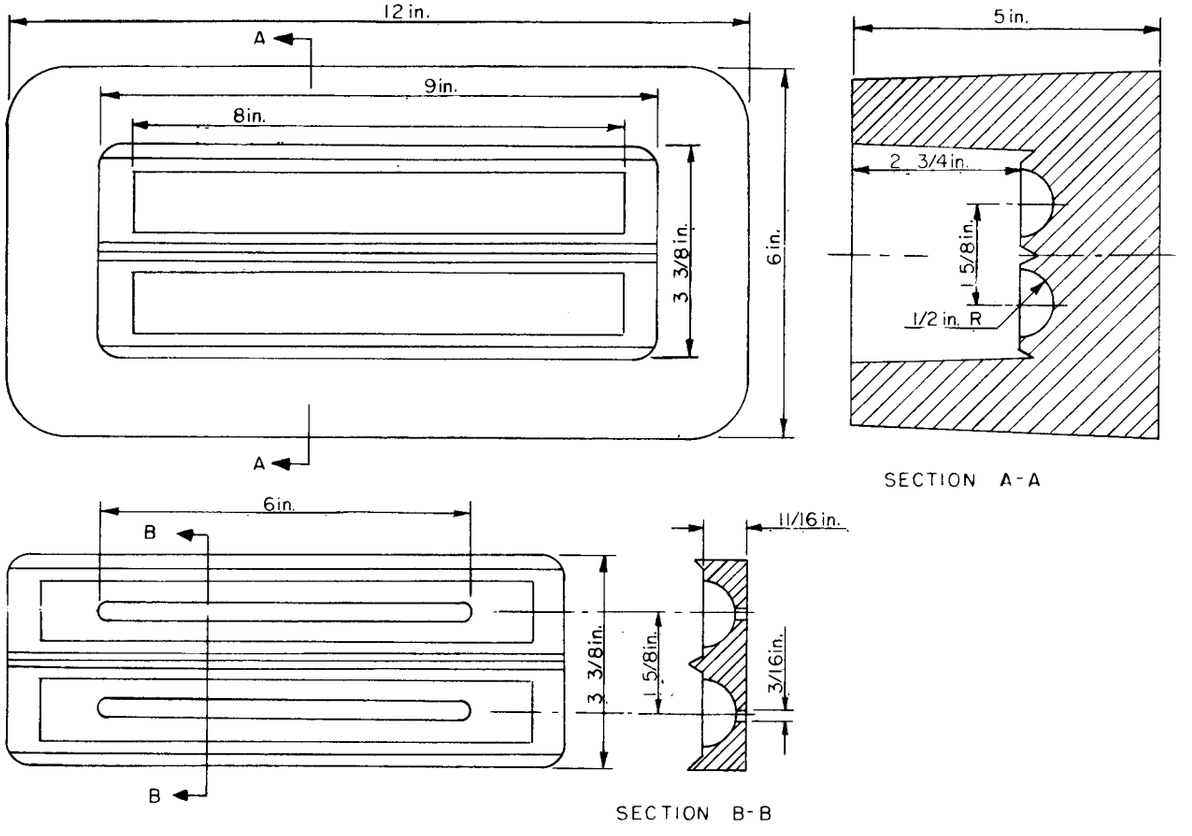
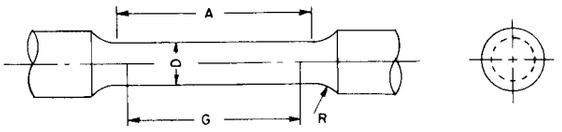


FIG. 4 MOLD FOR MODIFIED KEEL BLOCK



Dimensions	Standard Specimen, in.	Small Size Specimens Proportionate to Standard, in.	
	½ Round	0.350 Round	0.250 Round
G—Gage length	2.000 ± 0.005	1.4 ± 0.005	1.0 ± 0.005
D—Diameter (Note 1)	0.500 ± 0.010	0.350 ± 0.007	0.250 ± 0.005
R—Radius of fillet	⅜, min	⅜, min	¼, min
A—Length of reduced section (Note 2)	2¼, min	1¾, min	1¼, min

NOTE 1—The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 0.005 in. larger in diameter than the center on the standard specimen, and not more than 0.003 in. larger in diameter than the center on the small size specimens.

NOTE 2—If desired, on the small size specimens the length of the reduced section may be increased to accommodate an extensometer. However, reference marks for measurement of elongation should nevertheless be spaced at the indicated gage length.

NOTE 3—The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. If the ends are to be held in grips it is desirable, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

FIG. 5 STANDARD $^{1}/_{2}$-in. ROUND TENSION TEST SPECIMEN WITH 2-in. GAGE LENGTH AND EXAMPLES OF SMALL SIZE SPECIMENS PROPORTIONAL TO THE STANDARD SPECIMEN

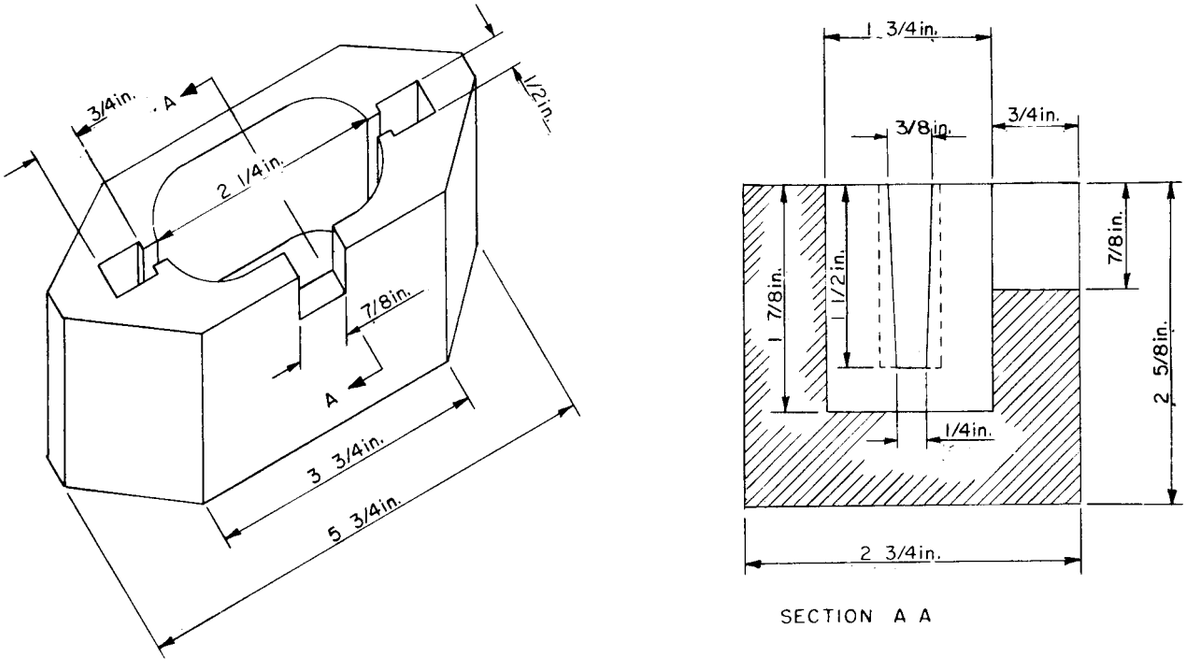
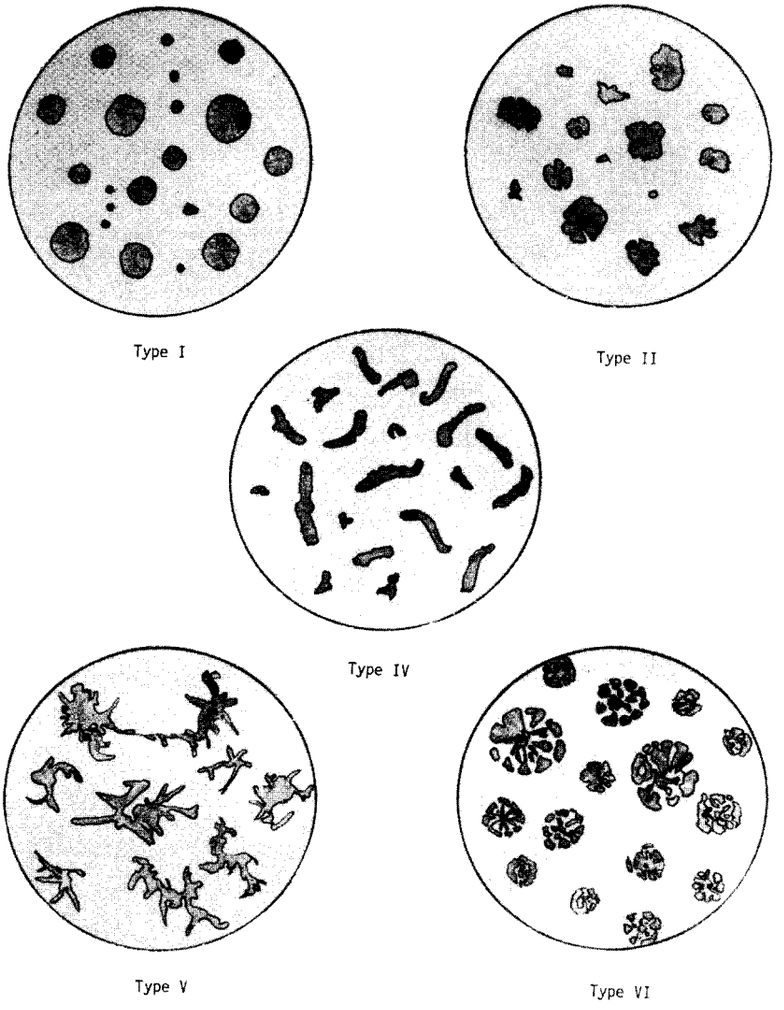


FIG. 6 TEST COUPONS FOR MICROSCOPICAL EXAMINATION OF DUCTILE IRON



NOTE—Graphite types are identical with Plate 1 of Method A 247 and are so identified.

FIG. 7 SUGGESTED CLASSIFICATION OF GRAPHITE FORM IN DUCTILE CAST IRON

TABLE 1
MINIMUM THICKNESS OF REPAIRED SECTIONS

Iron Pipe Size Plug, in.	Minimum Thickness Repaired Section, in.
1/8	11/32
1/4	7/16
3/8	1/2
1/2	21/32
3/4	3/4
1	13/16
1 1/4	7/8
1 1/2	15/16
2	1

TABLE 2
MINIMUM RADIUS OF REPAIRED SECTIONS

Iron Pipe Size Plug, in.	Minimum Radius of Cylinder or Cone, in.
1/8	9/16
1/4	11/16
3/8	1 1/16
1/2	1 1/4
3/4	2
1	2 1/2
1 1/4	4
1 1/2	5 1/4
2	8 1/8

TABLE 3
MINIMUM LIGAMENT BETWEEN PLUGS[A,B]

Nominal Plug Diameter, in.	Minimum Ligament Between Plugs, in.			
	1/8, 1/4, 3/8	1/2, 1/4	1, 1 1/4	1 1/2, 2
1/8, 1/4, 3/8	2 5/8	4 1/8	6 5/8	9 1/2
1/2, 3/4	4 1/8	4 1/8	6 5/8	9 1/2
1, 1 1/4	6 5/8	6 5/8	6 5/8	9 1/2
1 1/2, 2	9 1/2	9 1/2	9 1/2	9 1/2

[A] Based on efficiency of 80%.

[B] Example: Assume three plugs are required for repair, one 1/8 in., one 3/8 in., and one 1 1/2 in. The minimum distance permitted is as follows:

Ligament distance between 1/8 and 3/8 in. plugs is 2 5/8 in.
Ligament distance between 1/8 and 1 1/2 in. plugs is 9 1/2 in.
Ligament distance between 3/8 and 1 1/2 in. plugs is 9 1/2 in.

SUPPLEMENTARY REQUIREMENT

The following supplementary requirement shall not apply unless specified in the purchase order.

S1. A microstructure test lug is to be cast attached to the casting at the location designated on the casting drawing. The microstructure of the test lug shall be essentially ferrite and contain no massive carbides.

SPECIFICATION FOR WROUGHT AUSTENITIC STAINLESS STEEL PIPING FITTINGS

SA-403/SA-403M

(Identical to ASTM Specification A 403/A 403M-95 except for clarified heat treatment requirements in 6.1.) 98

1. Scope

98 **1.1** This specification covers two general classes, WP and CR, of wrought austenitic stainless steel fittings of seamless and welded construction covered by the latest revision of ANSI B16.9, ANSI B16.11, ANSI B16.28, MSS Standard Practice SP-79 and MSS Standard Practice SP-43 and MSS SP-95. Fittings differing from these standards may be furnished in accordance with Supplementary Requirement S9.

1.1.1 Class WP fittings are subdivided into four subclasses: Classes WP-S, WP-W, WP-WX and WP-WU. They are manufactured to the requirements of ANSI B16.9, B16.11, B16.28, or MSS Standard Practice SP-79, and they shall have pressure ratings compatible with 9.2. Class WP-S fittings are those manufactured from seamless product by a seamless method of manufacture (marked with class symbol WP-S); Class WP-W fittings contain welds where the fitting fabrication or construction welds have been radiographed (marked with class symbol WP-W); Class WP-WX fittings are those which contain welds where all welds have been radiographed (marked with class symbol WP-WX); and Class WP-WU fittings are those which contain welds where all welds have been ultrasonically tested (marked with class symbol WP-WU).

1.1.2 Class CR fittings are those manufactured to the requirements of MSS SP-43, and they shall have pressure ratings compatible with 9.3.

1.2 This specification does not apply to cast fittings. Cast austenitic-steel piping fittings are covered by Specifications A 351/A 351M, A 743/A 743M, and A 744/A 744M.

1.3 Optional supplementary requirements are provided. When desired, one or more may be specified in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 351/A 351M Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure Containing Parts

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, and Nickel-Base Corrosion Resistant for General Application
A 744/A 744M Specification for Castings, Iron-Chromium-Nickel and Nickel-Base Corrosion Resistant for Severe Service
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
E 165 Practice for Liquid Penetrant Inspection Method

2.2 *ANSI Standards:*
ANSI B16.9 Factor-Made Wrought Steel Butt-Welding Fittings
ANSI B16.11 Forged Steel Fittings, Socket-Welding and Threaded
ANSI B16.28 Wrought Steel Butt-Welding Short Radius Elbows and Returns

98 **2.3** *MSS Standards:*
MSS SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions
MSS SP-43 Standard Practice for Light Weight Stainless Steel Butt-Welding Fittings
MSS SP-79 Socket-Welding Reducer Inserts
MSS SP-95 Swage(d) Nipples and Bull Plugs

2.4 *ASME Boiler and Pressure Vessel Code:*
Section VIII Division I, Pressure Vessels
Section IX Welding Qualifications

2.5 *AWS Standards:*
A5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes
A5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes

2.6 *ASNT:*
SNT-TC-1A (1984) Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Ordering Information

3.1 Orders for fittings under this specification shall include the following information:

3.1.1 Quantity, number of fittings of each kind,

3.1.2 Description of fitting and nominal dimension (standard or special),

3.1.3 Steel composition by grade designation,

3.1.4 Class WP or CR shall be specified. Class WP fittings may be further defined by specifying Class WP-S, WP-W, WP-WX, or WP-WU,

3.1.4.1 Unless Class WP-S, WP-W, WP-WX, or WP-WU is specified by the purchaser, any may be furnished at the option of the supplier,

3.1.4.2 Class CR fittings shall not be substituted for fittings ordered to Class WP, but Class WP may be substituted for Class CR,

3.1.5 Additional requirements, if any (see 15.6), and 98

3.1.6 Supplementary requirements if any. 98

4. Material

4.1 The material for fittings shall consist of forgings, bars, plates, or seamless or welded tubular products that conform to the chemical requirements in Table 1.

4.2 The steel shall be melted by one of the following processes:

4.2.1 Electric furnace (with separate degassing and refining optional),

4.2.2 Vacuum furnace, or

4.2.3 One of the former followed by vacuum or electroslag-consumable remelting.

4.3 If secondary melting is employed, the heat shall be defined as all ingots remelted from a primary heat.

5. Manufacture

5.1 *Forming* — Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious defects in the fittings.

5.2 All classes of fittings shall be heat treated in accordance with Section 6.

5.3 Fittings ordered as Class WP-S shall be of seamless construction and shall meet all requirements of ANSI B16.9, B16.11, B16.28, or MSS SP-79.

5.4 Fittings ordered as Class WP-W shall meet the requirements of ANSI B16.9 or B16.28 and (*1*) shall have all welds made by the fitting manufacturer and all pipe welds made with the addition of filler metal

radiographically examined throughout the entire length in accordance with the code requirements stated in 5.5; and (*2*) shall not require radiography of the starting pipe weld if the pipe was welded without the addition of filler metal. In place of radiographic examination, welds made by the fitting manufacturer may be ultrasonically examined in accordance with the code requirements stated in 5.6.

5.5 Fittings ordered as Class WP-WX shall meet the requirements of ANSI B16.9 or B16.28 and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, radiographically examined throughout their entire length in accordance with Paragraph UW-51 of Section VIII, Division I, of the ASME Boiler and Pressure Vessel Code.

5.6 Fittings ordered as Class WP-WU shall meet the requirements of ANSI B16.9 or B16.28 and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, ultrasonically examined throughout their entire length in accordance with Appendix 12 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

5.7 The radiography or ultrasonic examination of welds for this class of fittings may be done at the option of the manufacturer, either prior to or after forming.

5.8 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

5.9 Fittings covered in MSS SP-43 and ordered as CR shall meet the requirements of MSS SP-43 and do not require nondestructive examination.

5.10 All classes of fittings shall have the welders, welding operators, and welding procedures qualified under the provisions of Section IX of the ASME Boiler and Pressure Vessel Code except that starting pipe welds made without the addition of filler metal do not require such qualification.

5.11 All joints welded with filler metal shall be finished in accordance with the requirements of Paragraph UW-35(a) of Section VIII, Division I, of the ASME Boiler and Pressure Vessel Code.

5.12 Fittings machined from bar shall be restricted to NPS 4 or smaller. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

5.12.1 All caps machined from bar shall be examined by liquid penetrant in accordance with Supplementary Requirement S7.

5.13 Weld buildup is permitted to dimensionally correct unfilled areas produced during cold forming of stub ends. Radiographic examination of the weld buildup shall not be required provided that all the following steps are adhered to:

5.13.1 The weld procedure and welders or welding operators meet the requirements of 5.10.

5.13.2 Annealing is performed after welding and prior to machining.

5.13.3 All weld surfaces are liquid penetrant examined in accordance with Appendix 8 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

5.13.4 Repair of areas in the weld is permitted, but 5.13.1, 5.13.2, and 5.13.3 must be repeated.

5.13.5 Fittings shall be marked with the symbol WBU following the alloy designation and classification marking (for example: WP 304/304 L-S/WBU, WP 316-W/WBU, etc.). 98

6. Heat Treatment

6.1 All fittings shall be furnished in the heat-treated condition. For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. The heat-treat procedure, except for those grades listed in 6.2, shall consist of solution annealing the fittings at a minimum temperature of 1900°F [1040°C] until the chromium carbides go into solution, and then cooling at a sufficient rate to prevent reprecipitation.

6.2 Grades 321H, 347H, and 348H shall be solution annealed at 1925°F [1050°C] minimum. S31254 shall be solution annealed at 2100°F [1150°C] minimum. S33228 shall be solution annealed at 2050°F [1120°C], minimum. S34565 shall be solution annealed in the range 2050°F [1120°C] to 2140°F [1170°C]. The maximum temperature for solution annealing grades 321, 321H, 347, and 347H under 6.1 and 6.2 shall be 2100°F [1150°C]. 98

6.3 All welding shall be done prior to heat treatment.

6.4 Fittings machined directly from solution-annealed forgings and bar stock need not be resolution annealed.

7. Chemical Composition

7.1 The chemical composition of each cast or heat used shall be determined and shall conform to the requirements of the chemical composition for the respective grades of materials listed in Table 1. The ranges as shown have been expanded to include variations of the chemical analysis requirements that are listed in the various specifications for starting materials (pipe, tube, plate, bar, and forgings) normally used in the manufacturing of fittings to this specification. Methods and practices relating to chemical analyses required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751. Product analysis tolerances in accordance with Specification A 480/A 480M are applicable.

98 **7.2** In fittings of welded construction, the alloy content (carbon, chromium, nickel, molybdenum, columbium, and tantalum) of the deposited weld metal shall conform to that required of the base metal or for equivalent weld metal as given in the AWS filler metal specification A5.4 or A5.9 (Type 348 Weld metal is listed in AWS A5.9, but not in AWS A5.4). Exceptions are when welding on Types 304L and 304 base metals, the deposited weld metal shall correspond, respectively, to AWS E308L (ER308L) and E308 (ER308); when welding on Type 321 base metal, the weld metal shall correspond to AWS Type E347 (ER347 or ER321); and, when welding on S31725, S31726, S31254 or S33228 base metal, the deposited weld metal shall correspond either to the alloy content of the base metal or to AWS A5.11 E NiCrMo · 3 (UNS W86112) (AWS A5.14 NiCrMo · 3 (UNS N06625)).

7.2.1 Supplementary Requirement S8 may be specified where 16-8-2 filler metal is required for joining thick sections of Types 316, 321, or 347 and has adequate corrosion resistance for the intended service.

8. Tensile Properties

8.1 The tensile properties of the fitting material shall conform to the requirements of Table 2. The testing and reporting shall be performed in accordance with Methods and Definitions A 370.

8.2 Records of the tension test made on the starting material shall be certification that the material of the fitting meets the requirements of this specification provided that heat treatments are the same.

8.3 If the raw material was not tested, or if the heat treatment of the raw material was different than the heat treatment of the fitting, the fitting manufacturer shall perform at least one tension test per heat on material representative of the fitting, and in the same condition of heat treatment as the fitting it represents. Qualification of welding procedures shall be in accordance with 5.8.

8.4 If a tension test through the weld is desired, Supplementary Requirement S2 should be specified.

9. Hydrostatic Tests

9.1 Hydrostatic testing is not required by this specification.

9.2 Each fitting of Class WP shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure equal to that prescribed for the specified matching pipe or equivalent material.

9.3 Each fitting of Class CR, except tees covered in 9.3.1, shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure based on the ratings in MSS SP-43.

9.3.1 Class CR tees fabricated using intersection welds shall be capable of passing a hydrostatic test based on 70% of the ratings in MSS SP-43.

10. Surface Quality

10.1 Fittings supplied under this specification shall be examined visually. Selected typical surface discontinuities shall be explored for depth. The fittings shall be free from surface discontinuities that penetrate more than 5% of the specified nominal wall thickness, except as defined in 10.3 and 10.4, and shall have a workmanlike finish.

10.2 Surface discontinuities deeper than 5% of the specified nominal wall thickness, except as defined in 10.3 and 10.4, shall be removed by the manufacturer by machining or grinding to sound metal, and the repaired areas shall be well faired. The wall thickness at all points shall be at least 87½% of the specified nominal wall thickness, and the diameters at all points shall be within the specified limits.

10.3 Surface checks (fish scale) deeper than $\frac{1}{64}$ in. [0.4 mm] shall be removed.

10.4 Mechanical marks deeper than $\frac{1}{16}$ in. [1.6 mm] shall be removed.

10.5 When the removal of a surface discontinuity reduces the wall thickness below 87½% of the specified nominal wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in 10.6.

10.6 *Repair by Welding:*

10.6.1 Repair of unacceptable imperfections in the base metal is permissible for fittings made to the dimensional standards listed in 1.1 or for other standard fittings made for stock by the manufacturer. Prior approval of the purchaser is required to repair special fittings made to the purchaser's requirements. Welding of unacceptable imperfections in no case shall be permitted when the depth of defect exceeds $33\frac{1}{3}$% of the nominal wall thickness or the defect area exceeds 10% of the surface area of the fitting.

10.6.2 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.6.3 The composition of the weld deposits shall be in accordance with 7.2 and in accordance with the procedure qualification for the applicable material.

10.6.4 Unacceptable imperfections shall be removed by mechanical means or by thermal cutting or gouging methods. Cavities prepared for welding shall be examined with liquid penetrant in accordance with Practice E 165. No cracks are permitted in the prepared cavities. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

10.6.5 The weld repair shall be permanently identified with the welder's stamp or symbol in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code.

10.6.6 Weld repair area(s) shall be blended uniformly to the base metal and shall be examined by liquid penetrant in accordance with Practice E 165. No cracks are permitted in the weld or surrounding $\frac{1}{2}$ in. [12.7 mm] of base metal. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

10.6.7 After weld repair, material shall be heat treated in accordance with Section 6.

10.7 The fittings shall be free of scale and shall be passivated.

11. Dimensions

11.1 For fittings covered by ANSI B16.9, ANSI B16.11, ANSI B16.28, MSS SP-43, or MSS SP-79, the sizes, shapes, and dimensions of the fittings shall be as specified in those standards.

11.1.1 Fittings of size or shape differing from these standards, but meeting all other requirements of this specification, may be furnished in accordance with Supplementary Requirement S9.

12. Inspection

12.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with this specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All examinations and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

12.2 Other tests, when agreed upon, shall be made from material of the lots covered in the order.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the tests, the producer or supplier may make claim for rehearing.

13.2 Fittings that develop defects in shop working or application operations may be rejected. Upon rejection, the manufacturer shall be notified promptly in writing.

14. Certification

14.1 When requested by the purchaser, the manufacturer shall provide a certificate of conformance to this specification. In addition, if requested to provide test reports, the manufacturer shall also provide the following where applicable:

14.1.1 Chemical results, Section 7 (Table 1),

14.1.2 Tensile results, Section 8 (Table 2). Report yield strength and ultimate strength in ksi [MPa] and percent elongation.

14.1.3 Type of heat treatment, Section 6 or Supplementary Requirement S10,

14.1.4 Starting material; plate, bar, pipe (specify welded or seamless), forging,

14.1.5 Seamless or welded construction,

14.1.6 Any supplemental testing required by the purchase order, and

14.1.7 Heat identification.

14.2 Certification shall state whether welds have been examined radiographically or ultrasonically.

15. Product Marking

15.1 All fittings shall have the prescribed information stamped or otherwise suitably marked on each fitting in accordance with the latest edition of MSS SP-25.

15.2 Marking paint or ink shall not contain harmful amounts of chlorides, metals, or metallic salt, such as zinc or copper, that cause corrosive attack on heating. On wall thicknesses thinner than 0.083 in. [2.1 mm], no metal impression stamps shall be used. Vibrating pencil marking is acceptable.

15.3 The prescribed information for butt-welding fittings shall be: the manufacturer's name or trademark (Note 1), schedule number or nominal wall thickness designation, size, class, grade (Table 1), and the heat number or manufacturer's heat identification. The "S" suffix need not be added to the material grade for threaded or socket-welded fittings.

15.3.1 The prescribed information for cold-formed stub ends with weld buildup shall be: the manufacturer's name or trademark (Note 1), schedule number or nominal wall thickness designation, class, size, grade (listed in Table 1) WBU, and heat number or manufacturer's heat identification.

15.4 The prescribed information for threaded or socket-welding fittings shall be: the manufacturer's name or trademark (Note 1), pressure class or schedule number, class and grade (Table 1), and the heat number or manufacturer's heat identification.

NOTE 1 — For purposes of identification marking, the manufacturer is considered the organization that certifies that the piping component complies with this specification.

15.5 Fittings meeting the chemical and mechanical property requirements of Tables 1 and 2 for more than one class or grade may be marked with more than one class or grade designation, such as WP304/304H; WP304/304L; WP304/304L/304N; WP316/316L, etc.

15.6 *Bar Coding* — In addition to the requirements in 15.1, 15.2, 15.3, 15.4, and 15.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag. **98**

TABLE 1
CHEMICAL REQUIREMENTS[A]

Marking Symbol[A] Class and Grade												
WP Class Fittings	CR Class Fittings	C′	Mn′	P′	S′	Si′	Ni	Cr	Mo	Ti	N_2″	Others
WP 304	CR 304	0.08	2.00	0.045	0.030	1.00	8.00–11.0	18.0–20.0	. . .	. . .	. . .	. . .
WP 304H	CR 304H	0.04–0.10	2.00	0.045	0.030	1.00	8.00–11.0	18.0–20.0	. . .	. . .	. . .	. . .
WP 304L	CR 304L	0.035[B]	2.00	0.045	0.030	1.00	8.00–13.0	18.0–20.0	. . .	. . .	. . .	. . .
WP 304LN	CR 304LN	0.030	2.00	0.040	0.030	0.75	8.00–10.50	18.0–20.0	. . .	. . .	0.10–0.16	. . .
WP 304N	CR 304N	0.08	2.00	0.040	0.030	0.75	8.00–11.0	18.0–20.0	. . .	. . .	0.10–0.16	. . .
WP 309	CR 309	0.15	2.00	0.045	0.030	1.00	12.0–15.0	22.0–24.0	. . .	. . .	. . .	. . .
WP 310	CR 310	0.15	2.00	0.045	0.030	1.50	19.0–22.0	24.0–26.0	. . .	. . .	. . .	. . .
WP 316	CR 316	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .
WP 316H	CR 316H	0.04–0.10	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .
WP 316LN	CR 316LN	0.030	2.00	0.040	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	. . .	0.10–0.16	. . .
WP 316L	CR 316L	0.035[B]	2.00	0.045	0.030	1.00	10.0–16.0[C]	16.0–18.0	2.00–3.00	. . .	. . .	. . .
WP 316N	CR 316N	0.08	2.00	0.040	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	. . .	0.10–0.16	. . .
WP 317	CR 317	0.08	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.00–4.00	. . .	. . .	. . .
WP 317L	CR 317L	0.030	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.00–4.00	. . .	. . .	. . .
WP 321	CR 321	0.08	2.00	0.045	0.030	1.00	9.00–13.0	17.0–20.0	. . .	[D]	. . .	. . .
WP 321H	CR 321H	0.04–0.10	2.00	0.045	0.030	1.00	9.00–13.0	17.0–20.0	. . .	[E]	. . .	. . .
WP 347	CR 347	0.08	2.00	0.045	0.030	1.00	9.00–13.0	17.0–20.0	. . .	. . .	. . .	[F]
WP 347H	CR 347H	0.04–0.10	2.00	0.045	0.030	1.00	9.00–13.0	17.0–20.0	. . .	. . .	. . .	[G]
WP 348	CR 348	0.08	2.00	0.045	0.030	1.00	9.00–13.0	17.0–20.0	. . .	. . .	. . .	Ta[F] = 0.10 max
WP 348H	CR 348H	0.04–0.10	2.00	0.045	0.030	1.00	9.00–13.0	17.0–20.0	. . .	. . .	. . .	Ta[G] = 0.10 max
WP XM19	CR XM19	0.060	4.00–6.00	0.040	0.030	1.00	11.5–13.5	20.5–23.5	1.50–3.00	. . .	0.20–0.40	[J]
WP S31254	CR S31254	0.020	1.00	0.030	0.010	0.80	17.50–18.50	19.50–20.50	6.00–6.50	. . .	0.18–0.22	Cu 0.50–1.00
WP S31725	CF S31725	0.030	2.00	0.045	0.030	0.75	13.5–17.5	18.0–20.0	4.0–5.0	. . .	0.10 max	Cu 0.75 max
WP S31726	CR S31726	0.030	2.00	0.045	0.030	0.75	13.5–17.5	17.0–20.0	4.0–5.0	. . .	0.10–0.20	Cu 0.75 max
WP S34565	CR S34565	0.03	5.0–7.0	0.030	0.010	1.00	16.0–18.0	23.0–25.0	4.0–5.0	. . .	0.4–0.6	Cb = 0.1 max
WP S33228	CR S33228	0.04–0.08	1.0	0.020	0.015	0.30	31.0–33.0	26.0–28.0	. . .	. . .	. . .	Ce 0.05–0.10 Al 0.025 Cb 0.6–1.0

NOTES:

[A] In addition to the WP class designation, WP fittings shall be marked with the additional symbols indicated in 1.1.1 (that is; WP 304S, WP 304W, WP 304WX).

[B] For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040% is necessary in grades TP 304L and TP 316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.24 mm] in average wall thickness.

[C] On pierced tubing, the nickel may be 11.0–16.00%.

[D] The titanium content shall be not less than five times the carbon content and not more than 0.70%.

[E] The titanium content shall be not less than four times the carbon content and not more than 0.70%.

[F] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.10%.

[G] The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.10%.

[H] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

[I] Maximum, unless otherwise indicated.

[J] Columbium plus tantalum, 0.10–0.30%: vanadium, 0.10–0.30%.

TABLE 2
TENSILE REQUIREMENTS 98

Grade	Yield Strength, min, ksi [MPa]	Tensile Strength, min, ksi [MPa]
304, 304LN, 304H, 309, 310, 316, 316LN, 316H, 317, 317L, 321, 321H, 347, 347H, 348, 348H, S31725	30 [205]	75 [515]
304L, 316L	25 [170]	70 [485]
304N, 316N, S31725	35 [240]	80 [550]
XM-19	55 [380]	100 [690]
S31254	44 [300]	94 [650] to 119 [820]
S33228	27 [185]	73 [500]
S34565	60 [415]	115 [795]

	Elongation Requirements	
	Longitudinal	Transverse
Standard round specimen, or small proportional specimen, or strip-type specimen, minimum % in 4 *D*	28	20

SUPPLEMENTARY REQUIREMENTS FOR WELDING FITTINGS REQUIRING SPECIAL CONSIDERATION

One or more of the supplementary requirements described below may be included in the purchaser's inquiry or in the order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier.

S1. Product Analysis (Note 2)

S1.1 A product analysis shall be made for each heat of base metal and, if of welded construction, from each lot number of welding material of the fittings offered for delivery and shall conform to the requirements specified in Section 4.

S2. Tension Test (Note 2)

S2.1 One tension test shall be made on one fitting or representative test piece (Note 3) per lot (Note 4) of fittings. If the fittings are of welded construction, the tension specimen shall include the weld and be prepared so that the weld is at the midlength of the specimen.

NOTE 2 — If the results of any of the tests specified in Supplementary Requirements S1, S2, or S3 do not conform to requirements, retests may be made at the manufacturer's expense on additional fittings or representative test pieces of double the original number from the same heat or lot as defined in Supplementary Requirements S1, S2, or S3, each of which shall conform to the requirements specified.

NOTE 3 — Where the test specimen for the tension or intergranular corrosion bend test cannot be taken from a fitting due to size limitations, a representative test piece shall be obtained. The test piece shall be from the same lot it represents and shall have approximately the same amount of working. In addition, these pieces representing fittings manufactured from bars, plate, or forgings shall have a cross section equal to the greatest cross section of the fitting, and test pieces representing fittings manufactured from pipe shall have an outside diameter and wall thickness equal to those of the fitting. The test piece for fittings of welded construction shall be prepared to the same weld procedures and from the same heat of materials as the fittings it represents.

NOTE 4 — A lot shall consist of all fittings of the same type, size, and wall thickness, manufactured from one heat of material (and, if fabrication welding is performed using one lot number of electrode or one heat of weld wire), and heat treated using the same heat-treat cycle in either a continuous or batch-type furnace controlling within a range of 50°F [28°C] and equipped with recording pyrometers so that complete records of heat treatment are available.

S3. Intergranular Corrosion Bend Test (Note 1)

S3.1 One intergranular corrosion bend test shall be made on one fitting or representative test piece (Note 2) per lot (Note 3) of fittings. If the fittings are of welded construction, the bend specimen shall include the weld and be prepared so that the weld is at the midlength location of the specimen. Specimens containing a weld shall be bent so that the location of weld is at the point of maximum bend. The method of testing shall be in accordance with Practice E of Practices A 262.

S3.2 Types 304L, 316L, 317L, 321, 347, and 348 shall be tested after a heat treatment capable of producing sensitization. In the case of the other chromium-nickel steels (Series 300), the test shall be conducted on specimens representative of the material in the annealed condition.

S4. Ultrasonic Test

S4.1 Each fitting of the raw material from which each fitting is made shall be ultrasonically tested to determine its soundness. The method, where applicable, shall be in accordance with Practice A 388. Acceptance limits shall be specified by the purchaser. Personnel performing the examination shall be qualified in accordance with SNT-TC-1A.

S5. Photomicrographs

S5.1 Photomicrographs at 100 diameters shall be made, for information only, of the actual base metal structure from one fitting as furnished in each lot. The photomicrographs shall be identified as to fittings size, wall thickness, lot identification, and heat. The definition of "lot" shall be as specified by the purchaser.

S6. Surface Finish

S6.1 Machined surfaces shall have a maximum roughness of 250 μin. [6.4 μm] arithmetical average. All other surfaces shall be suitable for ultrasonic test.

S7. Liquid Penetrant Test

S7.1 All surfaces shall be liquid penetrant tested. The method shall be in accordance with Practice E 165. Personnel performing the examination shall be qualified in accordance with SNT-TC-1A.

S8. Special Filler Metal

S8.1 Filler metal shall be AWS Type E16-8-2 or ER 16-8-2 (AWS Specifications A5.4 and A5.9, respectively). Fittings welded with 16-8-2 weld metal shall be marked WP ____ HRW or CR ____ HRW, as appropriate.

S9. Special Fittings

S9.1 Partial compliance fittings of size and shape not conforming to the dimensional requirements of ANSI B16.9, B16.11, B16.28, MSS SP-79, or MSS SP-95 shall meet all other requirements of this specification. In addition to the marking required in Section 15, the grade designation symbol shall be followed by the symbol "S9". 98

S10. Stabilization Treatment

S10.1 Grades 321, 347, and 348 shall receive a stabilization treatment instead of a solution anneal as required by 6.2. The stabilization treatment shall consist of holding the fittings at 1500 to 1600°F [815 to 870°C] for a minimum of 2 h/in. [4.7 min/mm] of thickness and then cooling in the furnace or in air. In addition to the marking required in Section 15, the grade designation symbol shall be followed by the symbol "S10".

SPECIFICATION FOR WELDED LARGE DIAMETER AUSTENITIC STEEL PIPE FOR CORROSIVE OR HIGH-TEMPERATURE SERVICE

SA-409/SA-409M

(Identical with ASTM Specification A 409/A 409M-95a$^{\epsilon 1}$ except for clarified heat treatment requirements in 5.3.1 and the addition of the following additional requirements.) 98

All products furnished under this SA specification are intended for application under the rules of Section III for Class 3 Piping or for application under the rules of Section VIII-1. Furnishing of such products is limited to manufacturers who hold the appropriate ASME Code Symbol Stamp. Weld procedures, welders, and welding machine operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX. The product shall meet all applicable requirements of Class 3 piping or Section VIII-1, if applicable including those requirements pertaining to heat treatment and butt welds. Authorized inspection at the point of manufacture and application of the appropriate Code Symbol Stamp is required.

The applicable ASME partial data report form, signed by an authorized inspector, and a certified mill test report shall be furnished for each lot of pipe. The term "lot" applies to all pipe of the same mill heat of material and wall thickness which is heat treated in one furnace charge. For pipe which is not heat treated or which is heat treated in a continuous furnace, a lot shall consists of each 200 ft. [61 m] or fraction thereof of all pipe of the same mill heat of material and wall thickness, subjected to the same heat treatment. For pipe which is heat treated in a batch-type furnace which is automatically controlled within a 50°F range and is equipped with recording pyrometer so that the heating records are available, a lot may be defined the same as for continuous furnaces. Each length of pipe shall be marked in such a manner as to identify each such piece with the "lot" and the representative certified mill test report.

1. Scope

1.1 This specification covers straight seam or spiral seam electric-fusion-welded, light-wall, austenitic chromium-nickel alloy steel pipe for corrosive or high-temperature service. The sizes covered are NPS 14 to 30 with extra light (Schedule 5S) and light (Schedule 10S) wall thicknesses. Table X1.1 shows the wall thicknesses of Schedule 5S and 10S pipe. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.2 Several grades of alloy steel are covered as indicated in Table 1.

1.3 Optional supplementary requirements are provided. These call for additional tests to be made, and when desired shall be stated in the order, together with the number of such tests required.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*

A 240 Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ASME Boiler and Pressure Code:*
Section IX Welding Qualifications

2.3 *AWS Standards:*
A 5.22 Flux Cored Arc Welding
A 5.30 Consumable Weld Inserts for Gas Tungsten Arc Welding
A 5.4 Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes
A 5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes
A 5.11 Nickel and Nickel-Alloy Covered Welding Electrodes
A 5.14 Nickel and Nickel-Alloy Bare Welding Rods and Electrodes

3. Ordering Information

3.1 Orders for material to this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimeters, or number of lengths),

3.1.2 Name of material (straight seam or spiral seam electric-fusion-welded austenitic steel pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (outside diameter and schedule number, or wall thickness),

3.1.5 Length (specific or random) (Section 11),

3.1.6 End finish (Section on Ends of Specification A 530/A 530M),

3.1.7 Optional requirements (5.2.1 to 5.2.3 removal of weld bead; 5.3.2, special heat treatment; 15.2, nondestructive test; 10.1.1, outside diameter tolerance; 11.2, length circumferentially welded; 12.3, repair by welding and heat treatment subsequent to repair welding; 12.4, sand blasted or pickled; 17.1 Certification; Supplementary Requirements S1 to S6).

3.1.8 Specification designation, and

3.1.9 Special requirements.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 If a specific type of melting is required by the purchaser it shall be stated on the order.

5.2 *Welding:*

5.2.1 The welds shall be made by the manual or automatic electric-welding process. For manual welding, the operator and procedure shall be qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX. Unless otherwise specified on the purchase order, the pipe may be welded with or without filler metal when the automatic electric-welding process is used.

5.2.2 The weld surface on either side of the weld may be flush with the base plate or may have a reasonably uniform crown, not to exceed $^{1}/_{16}$ in. [2 mm]. Any weld reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement should be reasonably smooth and free from irregularities. The weld metal shall be fused uniformly into the plate surface. No concavity of contour is permitted unless the resulting thickness of weld metal is equal to or greater than the minimum thickness of the adjacent base metal.

5.2.3 Weld defects, as determined by specified inspection requirements, shall be repaired by removal to sound metal and rewelding.

5.3 *Heat Treatment:*

5.3.1 Except as provided in 5.3.2, all pipe shall be furnished in the heat-treated condition. For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. The heat-treatment procedure shall consist of heating the material to a minimum temperature of 1900°F [1040°C], except for S31254 and S30815 which shall be heat treated to 2100°F [1150°C] and 1920°F [1050°C] respectively and for S24565 which shall be heat treated in the range 2050°F [1120°C] to 2140°F [1170°C], all materials to be followed by quenching in water or rapidly cooling by other means.

5.3.2 The purchase order shall specify one of the following conditions if the heat-treated condition specified in 5.3.1 is not desired by the purchaser:

5.3.2.1 A final heat-treatment temperature under 1900°F [1040°C]. Each pipe supplied under this requirement shall be stenciled with the final heat-treatment temperature in degrees Fahrenheit or degrees Celsius after the suffix "HT". Controlled structural or special service characteristics may be specified as a guide for the most suitable heat treatment.

5.3.2.2 No final heat treatment of pipe fabricated of plate, that has been solution heat treated at temperatures required by this specification. Each pipe supplied under this requirement shall be stenciled with the suffix "HT-O".

5.3.2.3 No final heat treatment of pipe fabricated of plate, that has not been solution heat treated. Each pipe supplied under this requirement shall be stenciled with the suffix "HT-SO".

5.4 A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP321, TP347, and TP348. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S5).

6. Chemical Composition

6.1 Each type of stainless steel or alloy shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 Unless otherwise specified in the purchase order, the chemical composition of the welding filler metal shall conform to the requirements of the applicable AWS specification for the corresponding grade shown in Table 2. Grades with no filler metal classification indicated shall be welded with filler metals producing deposited weld metal having a composition in accordance with the chemical composition specified in Table 1. The method of analysis for nitrogen and cerium shall be a matter of agreement between the purchaser and manufacturer. The purchaser may choose a higher-alloy filler metal when needed for corrosion resistance.

7. Tensile Requirements

7.1 The tensile properties of the plate or sheet used in making the pipe shall conform to the requirements prescribed in Table 3. Certified mill test reports shall be submitted to the pipe manufacturer.

7.2 A transverse tension test taken across the welded joint of the finished pipe shall meet the same minimum tensile strength requirements as the sheet or plate. The weld section on the tension specimen shall be in the the same condition as the finished pipe (with or without bead as specified).

8. Mechanical Tests Required

8.1 *Tension Test* — One transverse tension test of the weld shall be made on each lot (Note 2) of finished pipe.

NOTE 2—The term "lot" applies to each 200 ft [60 m] or less of pipe of the same NPS and wall thickness (or schedule number) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace. When final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge. When no heat treatment is performed following final forming operations, the lot shall include each 200 ft [60 m] or less of pipe of the same NPS and wall thickness (or schedule number) which is produced from the same heat of steel.

8.2 *Transverse Guided-Bend Weld Test* — One test (two specimens) of the weld shall be made on each lot (Note 2) of finished pipe.

8.3 *Pressure or Nondestructive Electric Test* — Each length of pipe shall be subjected to a pressure test or a nondestructive electric test as prescribed in Section 5.

9. Permissible Variations in Wall Thickness

9.1 The minimum wall thickness at any point shall not be more than 0.018 in. [0.46 mm] under the specified wall thickness. (This tolerance is slightly more than commercial tolerances on sheet and plate to allow for possible loss of thickness caused by manufacturing operations.)

10. Permissible Variations in Dimensions

10.1 Permissible variations in dimensions shall not exceed the following at any point in each length of pipe.

10.1.1 *Specified Diameter* — Where the specified wall thickness is less than 0.188 in. [4.8 mm], the actual outside diameter, based on circumferential measurement,

shall not vary more than ±0.20% from the specified outside diameter. Where the specified wall thickness is 0.188 in. [4.8 mm] and heavier, the actual outside diameter, based on circumferential measurement, may vary a maximum of ±0.40% from the specified outside diameter. (Outside diameter tolerances closer than shown above may be obtained by agreement between the pipe manufacturer and purchaser.)

10.1.2 *Out-of-Roundness* — The difference between the major and the minor outside diameter shall not be more than 1.5% of the specified outside diameter.

10.1.3 *Alignment (Camber)* — Using a 10 ft [3.0 m] straightedge placed so that both ends are in contact with the pipe, the camber shall not be more than $^{3}/_{16}$ in. [4.8 mm].

11. Lengths

11.1 Unless otherwise specified in the purchase order, pipe of NPS 22 or less will be furnished in random lengths of 9 to 12 ft (Note 3). For outside diameters of over NPS 22, the minimum length will be 5 ft (Note 3).

NOTE 3—This value(s) applies when the inch-pound designation of this specification is the basis of purchase. The corresponding metric value(s) shall be agreed upon between the manufacturer and the purchaser.

11.2 When specified by the purchaser, two or more lengths may be circumferentially welded together to produce longer lengths.

11.3 Circumferentially welded joints shall be of the same quality as the longitudinal joints.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall have a workmanlike finish.

12.2 *Repair of Defects by Machining or Grinding* — Pipe showing moderate slivers or other surface defects may be machined or ground inside or outside to a depth which will ensure the removal of all defects providing the wall thickness is not reduced below the minimum specified in 9.1.

12.3 *Repair of Defects by Welding* — Defects which violate minimum wall thickness may be repaired by welding, but only with the approval of the purchaser. Areas shall be suitably prepared for welding with tightly closed defects removed by grinding. Open, clean defects, such as pits or impressions, may require no preparation. All welders, welding operators, and weld procedures shall be qualified to the ASME Boiler and Pressure Vessel Code, Section IX. Unless the purchaser specifies otherwise, pipe required to be heat treated under the provisions of 5.3 shall be heat treated or reheat treated following repair welding. Repaired lengths, where repair depth is greater than $^{1}/_{4}$ of the thickness, shall be pressure tested or repressure tested after repair and heat treatment (if any). Repair welds shall also be examined by suitable non-destructive examination techniques, including any techniques specifically required of the primary weld.

12.4 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

13. Test Specimens

13.1 Transverse tension and bend test specimens may be taken from a test plate of the same material as the pipe, made by attaching a formed cylinder to the end of the pipe and welding the abutting edges as a continuation and duplication of the seam of the pipe (run-off plate). As an alternative to a formed cylinder, the run-off plate may consist of flat plates with reinforcing bars clamped to the underside to prevent distortion. The run-off plate material shall be of the same heat, preferably shear croppings from the same plate.

13.2 When heat treatment is required, test specimens shall be cut from pipe after the heat treating has been completed, or specimens removed from the pipe prior to heat treating shall be heat treated with the pipe.

14. Transverse Guided-Bend Weld Tests

14.1 Two bend test specimens shall be taken transversely across the weld. One shall be subject to a face guided-bend test and the second to a root guided-bend test. One specimen shall be bent with the inside surface of the pipe against the plunger, and the other with the outside surface against the plunger.

14.2 The bend test shall be acceptable if no cracks or other defects exceeding $^{1}/_{8}$ in. [3 mm] in any direction are present in the weld metal or between the weld and the pipe metal after bending. Cracks which originate along the edges of the specimen during testing, and that are less than $^{1}/_{4}$ in. [6.5 mm] measured in any direction shall not be considered.

15. Pressure Tests

15.1 Where hydrostatic test equipment is not available, the pipe may be air or gas pressure tested with an internal pressure of 100 psi [700 kPa]. The weld and weld area shall be inspected with the use of soap solution or any other prepared solution which will detect the leakage of air or gas from the inside.

15.2 Instead of a pressure test, when mutually agreed upon between the purchaser and manufacturer, the entire weld area of each pipe, including circumferential welds, may be tested by nondestructive testing methods. These methods shall be capable of detecting both surface and subsurface defects.

16. Inspection

16.1 When specified in the purchase order, the pipe may be inspected at the manufacturer's plant by an inspector representing the purchaser. The inspector shall have entry at all times. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

17. Certification

17.1 Upon request of the purchaser in the contract or order, certification in accordance with the provisions of Specification A 530/A 530M shall be furnished. When specified on the purchase order or when a specific type of melting has been specified on the purchase order, the type of melting used shall also be reported to the purchaser or the purchaser's representative.

18. Product Marking

18.1 Each length of pipe manufactured in accordance with this specification shall have the following identifying marking within 12 in. [300 mm] of one end: manufacturer's name or trade-mark, specification number, grade number of the alloy, the manufacturer's heat number, size, and schedule number. Additional marking requirements for heat treatment are described in Supplementary Requirement S2.

18.2 Marking shall be legibly stenciled with a suitable paint or permanent marking compound, except when otherwise specified by the purchaser.

TABLE 1
CHEMICAL REQUIREMENTS

Grade	UNS Designations[A]	Composition, %											
		Carbon, max	Manganese, max	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium	Cerium	Other Elements
TP304	S30400	0.08	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .
TP304L	S30403	0.035	2.00	0.045	0.030	0.75 max	8.00–13.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .
TP309Cb	S30940	0.08	2.00	0.045	0.030	0.75 max	12.0–16.0	22.0–24.0	0.75 max	. . .	. . .	. . .	Cu 0.75 max; Cb + Ta 10 × C min, 1.10 max
TP309S	S30908	0.08	2.00	0.045	0.030	0.75 max	12.0–15.0	22.0–24.0	0.75 max	. . .	. . .	. . .	Cu 0.75 max
TP310Cb	S31040	0.08	2.00	0.045	0.030	0.75 max	19.0–22.0	24.0–26.0	0.75 max	. . .	. . .	. . .	Cu 0.75 max; Cb + Ta 10 × C min, 1.10 max
TP310S	S31008	0.08	2.00	0.045	0.030	0.75 max	19.0–22.0	24.0–26.0	0.75 max	. . .	. . .	. . .	Cu 0.75 max
TP316	S31600	0.08	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.0–3.0	. . .	. . .	. . .	
TP316L	S31603	0.035	2.00	0.045	0.030	0.75 max	10.0–15.0	16.0–18.0	2.0–3.0	. . .	. . .	. . .	. . .
TP317	S31700	0.08	2.00	0.045	0.030	0.75 max	11.0–14.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	. . .
TP321	S32100	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	. . .	[B]	. . .	. . .	. . .
TP347	S34700	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	. . .	. . .	[C]	. . .	. . .
TP348	S34800	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	. . .	. . .	[D]	. . .	. . .
. . .	S31254	0.020	1.00	0.030	0.010	0.80 max	17.5–18.5	19.5–20.5	6.00–6.50	. . .	. . .	. . .	Cu 0.50–1.00 N 0.180–0.220
. . .	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	. . .	. . .	. . .	0.03–0.08	N 0.14–0.20
. . .	S31725	0.03	2.00	0.045	0.030	0.75 max	13.5–17.5	18.0–20.0	4.0–5.0	. . .	. . .	. . .	Cu 0.75 max N 0.10 max
. . .	S31726	0.03	2.00	0.045	0.030	0.75 max	13.5–17.5	17.0–20.0	4.0–5.0	. . .	. . .	. . .	Cu 0.75 max N 0.10–0.20
. . .	S24565	0.03	5.0–7.0	0.030	0.010	1.00 max	16.0–18.0	23.0–25.0	4.0–5.0	. . .	0.1 max	. . .	N 0.4–0.6
. . .	N08367	0.03	2.00	0.040	0.030	1.00 max	23.50–25.50	20.00–22.00	6.00–7.00	. . .	. . .	. . .	Cu 0.75 max Ni 0.18–0.25

[A] New designation established in accordance with ASTM E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).
[B] The titanium content shall be not less than 5 times the carbon content and not more than 0.70%.
[C] The columbium plus tantalum content shall be not less than 10 times the carbon content and not more than 1.0%.
[D] The columbium plus tantalum content shall be not less than 10 times the carbon content and not more than 1.0%. The tantalum content shall be 0.10% maximum.

TABLE 2
FILLER METAL SPECIFICATIONS

Grade	UNS Designation	Filler Metal Classification and UNS Designation[A] for Applicable[B] AWS Specification											
		A5.4		A5.9		A5.11		A5.14		A5.22		A5.30	
		Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS
TP304	S30400	E308	W30810	ER308	S30880 W30840	...	...	...	...	E308T	W30831	IN308	S30880
TP304L	S30403	E308L	W30813	ER308L	S30883 W30843	...	...	...	...	E308T	W30835	IN308L	S30883
TP309Cb	S30940	E309Cb	W30917	...	...	...	...	...	...	...	...	...	...
TP310Cb	S31040	E310Cb	W31017	...	...	...	...	...	...	...	...	...	...
TP316	S31600	E316	W31610	ER316	S31680 W31640	...	...	...	...	E316T	W31631	IN316	S31680
TP316L	S31603	E316L	W31603	ER316L	S31683 W31643	...	...	...	...	E316LT	W31635	IN316L	S31683
TP317	S31700	E317	W31700	ER317	S31783 W31743	...	...	...	...	E317T	W31731	IN317	S31780
TP321	S32100	E347	W34710	ER321	S32180 W32140	...	...	...	...	E347T	W34733	IN348	S34780
				ER347	S34780 W34740								
TP347	S34700	E347	W34710	ER347	S34780 W34740	...	...	...	...	E347T	W34733	IN348	S34780
TP348	S34800	E347	W34710	ER347	S34780 W34740	...	...	...	...	E347T	W34733	IN348	S34780
...	S31254	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	NO6625	...	...	...	...
...	S31725	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	NO6625	...	...	...	...
...	S31726	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	NO6625	...	...	...	...
...	S24565	...	...	...	...	...	...	...	...	...	...	...	...
...	N08367	...	...	...	...	ENiCrMo-3	W86112	ERNiCrMo-3	NO6625	...	...	...	...

[A] New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).
[B] Choice of American Welding Society specification depends on the welding process used.

98

TABLE 3
TENSILE REQUIREMENTS

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]
TP304	S30400	75 [515]	30 [205]
TP304L	S30403	70 [485]	25 [170]
TP309Cb	S30940	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP316	S31600	75 [515]	30 [205]
TP316L	S31603	70 [485]	25 [170]
TP317	S31700	75 [515]	30 [205]
TP321	S32100	75 [515]	30 [205]
TP347	S34700	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
. . .	S31254	94 [650]	44 [300]
. . .	S30815	87 [600]	45 [310]
. . .	S31725	75 [515]	30 [205]
. . .	S31726	80 [550]	35 [240]
. . .	S24565	115 [795]	60 [415]
. . .	N08367		
	t ≤ 0.187	100 [690]	45 [310]
	t > 0.187	95 [655]	45 [310]

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 At the request of the purchaser a product analysis of one coupon representing finished sheet or plate from each heat shall be made by the pipe manufacturer. The drillings for product analysis may be taken from shear crop or test specimens. The results of product analysis shall conform to the requirements in Table 1 and shall be reported to the purchaser.

S2. Radiographic Examination

S2.1 Weld soundness shall be determined through radiographic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S3. Corrosion Requirements

S3.1 *Boiling Nitric Acid Test* — Except for Grade TP321, coupons representing finished pipe made of nonmolybdenum-bearing material (0.50% and less molybdenum) shall meet the requirement of the boiling nitric acid test conducted according to Practice C of Practices A 262. The condition of the test specimens and the corrosion rates are as follows: Type 347 and Type 348 shall be tested in the sensitized condition (heated for 1 h at 1240°F [675°C]) and the rate of penetration shall not exceed 0.0020 in. [0.05 mm]/month. All other nonmolybdenum-bearing types, except for Grade TP321, shown in Table 1 shall be tested in the annealed and unsensitized condition and the rate of penetration shall not exceed 0.0015 in. [0.04 mm]/month.

S3.2 *Acidified Copper Sulfate Test* — Coupons representing finished pipe made of molybdenum-bearing material and Type 321 (over 0.50% molybdenum) shall meet the requirements of the copper-copper sulfate-sulfuric acid test (intergranular corrosion test) conducted in accordance with Practice E of Practices A 262. The condition of the test specimen is as follows: All molybdenum-bearing types shown in Table 1 shall be tested in the annealed and unsensitized condition. Type 321 shall be tested in the sensitized condition (heated for 1 h at 1240°F [675°C]). All specimens shall meet the requirements of the prescribed bend test.

S4. Ferrite Control of Weld Deposits

S4.1 The ferrite content of the deposited weld metal in any length of pipe may be determined. The procedural details pertaining to this subject (that is, welding, plate and weld deposit chemistry, testing equipment and method, number and location of test sites, and ferrite control limits) shall be a matter for agreement between the purchaser and the manufacturer.

S5. Stabilizing Heat Treatment

S5.1 Subsequent to the heat treatment required in 5.3, Grades TP321, TP347, and TP348 shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S6. Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion test conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE 4—Practice E requires testing of the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S5 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium.

APPENDIX

(Nonmandatory Information)

X1. WALL THICKNESS OF SCHEDULE 5S AND SCHEDULE 10S

TABLE X1.1 PIPE DIMENSIONS

	Wall Thickness			
	Schedule 5S		Schedule 10S	
NPS Designator	in.	mm	in.	mm
14	0.156	3.96	0.188	4.78
16	0.165	4.19	0.188	4.78
18	0.165	4.19	0.188	4.78
20	0.188	4.78	0.218	5.54
22	0.188	4.78	0.218	5.54
24	0.218	5.54	0.250	6.35
30	0.250	6.35	0.312	7.92

SPECIFICATION FOR STEEL, SHEET, CARBON, FOR PRESSURE VESSELS

SA-414/SA-414M

(Identical with ASTM Specification A 414/A 414M-92(R1993)[E1], except for clarification of deoxidation practice in para. 5.3 and Tables 1 and 2.) **A99**

1. Scope

1.1 This specification covers hot-rolled carbon steel sheet for pressure vessels involving fusion welding or brazing. Welding and brazing technique is of fundamental importance and shall be in accordance with commercial practices.

1.2 The following grades are included in this specification:

	Mechanical Requirements			
	Yield Strength, min		Tensile Strength, min	
Grade	ksi	MPa	ksi	MPa
A	25	170	45	310
B	30	205	50	345
C	33	230	55	380
D	35	240	60	415
E	38	260	65	450
F	42	290	70	485
G	45	310	75	515

1.3 Hot-rolled carbon steel sheet is generally furnished in cut lengths and to decimal thickness only. Coils may be furnished provided tension test specimens are taken to represent the middle of the slab as required by 6.1.3. The purchaser should recognize this requires cutting the coils to obtain test samples and results in half-size coils. The sheet is furnished to the following size limits:

	Width, in. [mm]	
Thickness, in. [mm]	Over 12 to 48 [Over 300 to 1200]	Over 48 [Over 1200]
0.230 to 0.180 [6.0 to 4.5]	sheet	sheet (coils only)
Under 0.180 to 0.057 under [4.5 to 1.5]	sheet	sheet

1.4 The values stated in either U.S. inch-pound units or SI (metric) units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents, therefore, each system must be used independently of the other. Combining values of the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standard:*

A 568/A 568M Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements

3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 568/A 568M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information, as required, to describe the desired material adequately:

4.1.1 Designation or specification number, date of issue and grade,

4.1.2 Copper bearing steel, when required,

4.1.3 Special requirements, is required,

4.1.4 Condition — pickled (or blast cleaned), if required. (Material so ordered will be oiled unless ordered dry.),

4.1.5 Dimensions, including type of edges, and,

4.1.6 Cast analysis or test report request or both, if required.

NOTE 1 — A typical ordering description is as follows: "ASTM A 414, Grade A, Hot-Rolled Sheet, 0.100 in. [2.54 mm] by 36 in. [914.4 mm] by 96 in. [2438 mm], cut edges."

5. Chemical Requirements

5.1 *Cast or Heat Analysis* — The analysis of the steel shall conform to the requirements prescribed in Table 1.

5.1.1 Unspecified elements may be present. Limits on elements shall be as stated in Table 2.

5.1.1.1 Each of the elements listed in Table 2 shall be included in the report of the heat analysis. When the amount of an element present is less than 0.02%, the analysis may be reported as "<0.02%."

5.2 *Product, Check, or Verification Analysis* — Analyses may be made by the purchaser from finished material representing each heat.

A99 **5.3** *Deoxidation* — For Grades D through G, silicon or aluminum killed steel is required. See Table 1, footnote A.

6. Mechanical Property Requirements

6.1 *Tensile Strength:*

6.1.1 *Requirements* — Material as represented by the test specimen shall conform to the tensile requirements specified in Table 3.

6.1.2 *Number of Tests* — Two tensile tests shall be made from the product of each slab as rolled.

6.1.3 *Location and Orientation:*

6.1.3.1 Tensile test specimens shall be taken at locations representing the middle and back end of each slab as rolled.

6.1.3.2 Tensile test samples shall be taken from the full thickness of the sheet as rolled.

6.1.3.3 Tensile test specimens shall be taken from a location approximately halfway between the center of the sheet and the edge of the material as-rolled.

6.1.3.4 Tensile test specimens shall be taken with the axis of the test specimen perpendicular to the rolling direction (transverse test).

6.1.4 *Test Methods* — Yield strength shall be determined by either the 0.2% offset method or by the 0.5% extension under load method, unless otherwise specified.

7 Workmanship

7.1 The material shall be free from injurious defects (see Specification A 568/A 568M).

8. Finish and Appearance

8.1 *Surface Finish:*

8.1.1 Unless otherwise specified, the material shall be furnished without removing the hot-rolled oxide or scale.

8.1.2 When required, the material may be specified to be pickled or blast-cleaned.

8.2 *Oiling:*

8.2.1 Unless otherwise specified, the material shall be furnished not oiled.

8.2.2 When specified to be pickled or blast cleaned, the material shall be furnished oiled. When required, pickled or blast cleaned material may be specified to be furnished dry.

8.2.3 *Edges* — Unless otherwise specified, mill edges shall be furnished on material which has not had the hot-rolled oxide or scale removed and cut edges shall be furnished on material which has had the hot-rolled oxide or scale removed.

9. Certification and Reports

9.1 When requested, the manufacturer shall furnish copies of a test report showing the results of the cast analysis and mechanical property test made to determine compliance with this specification. The report shall include the purchase order number, specification number, and test identification number correlating the test results with material represented.

10. Product Marking

10.1 The name or brand of the manufacturer, heat and slab number, specification designation number, and grade shall be legibly and durably marked on each cut length sheet in two places not less that 12 in. [300 mm] from the edges. Cut length sheets, the maximum lengthwise and crosswise, dimensions of which do not exceed 72 in. [1800 mm], shall be legibly and durably marked in one place approximately midway between the center and a side edge. The manufacturer's test identification number shall be legibly and durably marked on each test specimen. Steel-die marking of sheets is prohibited.

10.2 For coil product, the information required in 10.1 shall be legibly and durably marked both on each coil and on a tag affixed to each coil.

11. Keywords

11.1 carbon steel sheet; pressure vessel steels; steel sheet

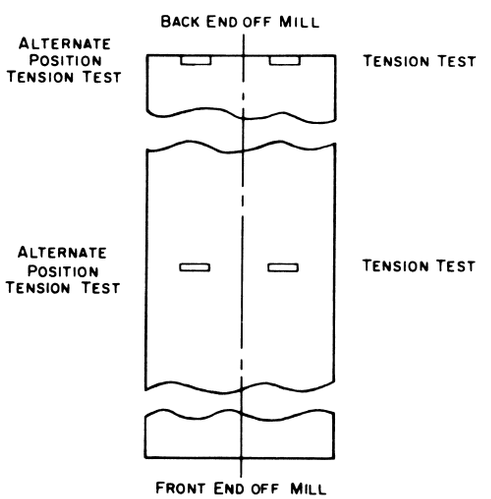


FIG. 1 LOCATION OF TEST SPECIMENS

A99

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %						
	Grade A Ladle	Grade B Ladle	Grade C Ladle	Grade D Ladle	Grade E Ladle	Grade F Ladle	Grade G Ladle
Carbon, max	0.15	0.22	0.25	0.25	0.27	0.31	0.31
Manganese, max	0.90	0.90	0.90	1.20	1.20	1.20	1.35
Phosphorus, max	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Silicon[A]	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Copper, when copper steel is specified, min	0.20	0.20	0.20	0.20	0.20	0.20	0.20

[A] Killed steel may be supplied upon request to the manufacturer for Grades A, B, and C. Killed steel is required for Grades D through G. When silicon killed steel is specified, a range of 0.15 to 0.30 shall be supplied. When aluminum killed steel is specified, a range of 0.020 to 0.080 total aluminum shall be specified.

TABLE 2
LIMITS ON UNSPECIFIED ELEMENTS (See 5.1.1)

Copper, max %[A]	Heat analysis	0.40
	Product analysis	0.43
Nickel, max %[A]	Heat analysis	0.40
	Product analysis	0.43
Chromium, max %[A,B]	Heat analysis	0.30
	Product analysis	0.34
Molybdenum, max %[A,B]	Heat analysis	0.12
	Product analysis	0.13
Vanadium, max %[C]	Heat analysis	0.03
	Product analysis	0.04
Columbium, max %[C]	Heat analysis	0.02
	Product analysis	0.03

[A] The sum of copper, nickel, chromium, and molybdenum shall not exceed 1.00% on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining unspecified elements will apply.
[B] The sum of chromium and molybdenum shall not exceed 0.32% on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining unspecified elements will apply.
[C] By agreement, the heat analysis limits for vanadium or columbium, or both, may be increased up to 0.10% and 0.05%, respectively.

TABLE 3
TENSILE REQUIREMENTS

	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Grade G
Tensile strength:							
min, ksi [MPa]	45 [310]	50 [345]	55 [380]	60 [415]	65 [450]	70 [485]	75 [515]
max, ksi [MPa]	60 [415]	65 [450]	70 [485]	75 [515]	85 [585]	90 [620]	95 [655]
Yield strength, min, ksi (MPa)[A]	25 [170]	30 [205]	33 [230]	35 [240]	38 [260]	42 [290]	45 [310]
Elongation in 2 in. (50 mm), min, percent:							
Under 0.230 to 0.145 [Under 6.0 to 3.8]	26	24	22	20	18	16	16
Under 0.145 to 0.089 [Under 3.8 to 2.2]	24	22	20	18	16	14	14
Under 0.089 to 0.057 [Under 2.2 to 1.5]	23	21	19	17	15	13	13
Elongation in 8 in. (200 mm), min, percent:							
Under 0.230 to 0.145 [Under 6.0 to 3.8]	20	18	16	14	12	10	10

[A] Yield strength determined by the 0.2% offset or 0.5% extension under load methods.

SPECIFICATION FOR PIPING FITTINGS OF WROUGHT CARBON STEEL AND ALLOY STEEL FOR LOW-TEMPERATURE SERVICE

SA-420/SA-420M 98

(Identical with ASTM Specification A 420/A 420M-95.)

1. Scope

98 **1.1** This specification covers wrought carbon steel and alloy steel fittings of seamless and welded construction, covered by the latest revision of ANSI B16.9, ANSI B16.11, ANSI B16.28, MSS SP-79, and MSS SP-95. Fittings differing from these ANSI and MSSVF standards shall be furnished in accordance with Supplementary Requirement S6. These fittings are for use in pressure piping and pressure vessel service at low temperatures.

1.2 Optional supplementary requirements are provided for fittings where a greater degree of examination is desired. When desired, one or more of these supplementary requirements may be specified in the order.

1.3 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275 Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 165 Practice for Liquid Penetrant Inspection

E 709 Practice for Magnetic Particle Examination

2.2 *ANSI Standards:*

B16.9 Factory-Made Wrought Steel Butt-Welding Fittings

B16.11 Forged Steel Fittings, Socket-Welding Threaded

B16.28 Wrought Steel Butt-Welding Short Radius Elbows and Returns

2.3 *ASME Boiler and Pressure Vessel Code:*

Section VIII Division 1, Pressure Vessels

Section IX Welding Qualifications

Section V Nondestructive Examination

2.4 *MSS Standards:* 98

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions

MSS SP-79 Socket Welding Reducer Inserts

MSS SP-95 Swage(d) Nipples and Bull Plugs

2.5 *ASNT Standards:*

ASNT(1984) Recommended Practice No. SNT-TC-1A

3. Ordering Information

98 **3.1** Orders for the material under this specification shall include the following, as required, to describe the material adequately.

3.1.1 Quantity, number of fittings of each kind,

3.1.2 Description of fittings and nominal dimension (standard or special),

3.1.3 Steel composition, by grade designation,

3.1.4 Construction, seamless or welded (unless seamless or welded is specified by the purchaser, either may be furnished at the option of the supplier),

3.1.5 Special marking requirements (see 17.1.2),

98 **3.1.6** Additional requirements, if any (see 17.6), and

98 **3.1.7** Supplementary requirements, if any.

4. Material

4.1 The material for fittings shall consist of forgings, bars, plates, seamless or fusion welded tubular products with filler metal added. It shall conform to the chemical requirements in Table 1, and be made by one of the following processes: open-hearth, basic-oxygen, or electric-furnace. The steels shall be made using recognized melting practices necessary to produce steels that shall meet the impact requirements of this specification.

5. Manufacture

5.1 Forging or forming operations may be performed by hammering, pressing, piercing, extruding, upsetting, working, bending, fusion-welding, or machining, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious defects in the fittings. Fittings machined from bar shall be restricted to NPS 4 or smaller. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

5.2 All welds, including welds in tubular products from which fittings are made, shall be (*1*) made by welders, welding operators and welding procedures qualified under the provisions of ASME Section IX, (*2*) heat treated in accordance with Section 6 of this specification, and (*3*) nondestructively examined throughout the entire length of each weld in accordance with Section 13 of this specification. The radiography of welds may be done either prior to or after forming at option of manufacturer. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

5.3 The welded joints of the fittings shall be finished in accordance with the requirements of Paragraph UW-35(a) of Section VIII, Division 1 of ASME Boiler and Pressure Vessel Code.

5.4 All butt-weld tees manufactured by cold-forming methods shall be liquid penetrant or magnetic particle examined by one of the methods specified in Supplementary Requirement S3 or S4. This examination shall be performed after final heat treatment by NDE personnel qualified under the provisions of ASNT Recommended Practice No. SNT-TC-1A. Only the sidewall areas of the tee need be examined. This area is defined by a circle that covers the area from the weld bevel of the branch outlet to the centerline of the body or run. Internal and external surfaces shall be examined when size permits accessibility. After the removal of any cracks, the tees shall be re-examined by the original method. Acceptable tees shall be marked with the symbol PT or MT, as applicable, to indicate compliance.

6. Heat Treatment

6.1 All fittings shall be furnished in the normalized, normalized and tempered, annealed, or quenched and tempered condition. All welding shall be completed prior to the austenitizing heat treatment.

6.2 The full thickness of the material from which impact test specimens are to be obtained shall be heat treated with a furnace charge as specified in 9.4.2 or 9.4.3.

6.3 After forming, the fittings shall be allowed to cool below the lower critical before applying one of the heat treatments listed in 6.1.

6.4 When the fittings are to be post-weld heat treated after being welded by the purchaser and when so specified in the order, the test specimens shall be subjected to the same post-weld heat treatment. The purchaser shall use the post-weld heat treatment shown in Table 2, unless otherwise specified in the order.

7. Chemical Composition

7.1 The steel shall conform to requirements of chemical composition for the respective material prescribed in Table 1. Methods, Practices, and Terminology A 751 shall apply.

7.2 The chemical composition of weld metal is not required to meet the same limits of the base material; however, the composition of the weld deposit shall be such that it meets the minimum mechanical and impact requirements of this specification. In general, the alloy content shall be similar to that of the base metal but should not exceed 6% except in the case of fittings of 9% nickel steel where the weld metal may be high alloy of an austenitic type.

8. Tensile Properties

8.1 The tensile properties of the fittings material shall conform to the requirements for the applicable grade of material as listed in Table 3. The testing shall be performed in accordance with Test Methods and Definitions A 370.

8.2 At least one tension test shall be made on each heat of material and in the same condition of heat treatment as the finished fittings it represents provided that the wall thickness of the fitting and the representative sample thickness do not vary more than ¼ in. [6 mm]. At least one tension test per heat of weld metal shall be made after heat treatment in the same manner as the base metal. Results need not be reported unless Supplementary Requirement S2 is specified.

8.3 Records of the tension tests shall be certification that the material of the fittings meets the tensile requirements of this specification.

9. Impact Test Properties

9.1 *Properties:*

98 **9.1.1** The notched-bar impact properties of the base metal and weld metal shall conform to the requirements of Table 4 or 5 for the applicable grade of materials.

9.1.2. *Retest* — When the average value of the three specimens equals or exceeds the minimum value permitted for a single specimen and the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, a retest of three additional specimens shall be made. The value for each of these retest specimens shall equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedure, a retest shall be allowed.

9.2 *Procedures:*

9.2.1 All material furnished under this specification shall be tested for impact resistance at the temperature for the respective grade in Table 6. Exceptions to these requirements are permissible when agreed upon between the purchaser and producer and specified in the order, in that the impact test may be made at temperatures different from those shown in Table 6, provided the test temperature is at least as low as the intended service temperature, and fittings are suitably marked in accordance with Section 17 to identify the reported test temperature.

9.2.2 The notched-bar impact test shall be made in accordance with the procedure for the simple-beam, Charpy-type test of Methods and Definitions A 370. Each impact test shall consist of breaking three specimens.

9.3 *Specimens:*

9.3.1 Notched-bar impact specimens shall be simple-beam, Charpy-type A with a V-notch in accordance with Test Methods and Definitions A 370. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable standard subsize impact specimens shall be used. When the size or shape of the finished fittings is insufficient to permit obtaining the smallest standard subsize impact specimens, an impact test by the fitting manufacturer will not be required. The material from which the specimens are taken shall be heat treated with a furnace charge in accordance with 9.4.2 or 9.4.3. Impact tests shall be made from either the raw material from which the fittings are made or from a finished fitting at the option of the manufacturer.

9.3.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the fitting while the axis of the "V" shall be perpendicular to the surface. On wall thickness over 1 in. [25 mm] the specimens shall be obtained with their longitudinal axis located ½ in. [13 mm] from the outer surface.

9.3.3 When testing welds, the notch of the specimen shall be in the welded joint and, where the diameter and wall thickness permit, the longitudinal axis of the specimen shall be transverse to the longitudinal axis of the weld. The axis of the notch shall be perpendicular to the surface.

9.4 *Number of Tests:*

9.4.1 A notched-bar impact test, consisting of breaking three specimens shall be made. Each test shall represent only such fittings from a heat that do not vary from the thickness of the material from which the test specimens are taken by more than $\frac{1}{4}$ in. [6 mm].

9.4.2 When heat treatment is performed in furnaces not equipped with calibrated recording pyrometers, one impact test shall be made for each heat in each heat-treatment load. Test specimens shall be included with each furnace charge. If this heat treatment is conducted in continuous-type furnaces not equipped with calibrated recording pyrometers, then one test per heat shall be conducted for each 5000 lb or 2550 kg (or less) of product.

9.4.3 When heat treatment is performed in furnaces controlled within a 50°F [28°C] range and equipped with calibrated recording pyrometers so that records of heat treatment are available, then one impact test from each heat is required, provided that all other heat treatments are conducted at the same temperatures and within the same 50°F [28°C] range as the furnace charge that contained the test specimens.

9.4.4 On fittings of welded construction, additional impact tests of the same number as required in 9.4.1 or 9.4.2 shall be made to test the weld metal.

9.4.5 Specimens showing defects while being machined or prior to testing may be discarded, and replacements shall be considered as original specimens.

9.5 *Retreatment:*

9.5.1 If the results of impact tests conducted in accordance with 9.4.2 and 9.4.3 fail to conform to the test requirements specified in 9.1, that group of fittings may be retreated and submitted for test. No group of fittings may be retreated more than twice.

10. Hydrostatic Tests

10.1 Hydrostatic testing of fittings is not required by this specification.

10.2 All fittings shall be capable of withstanding without failure, leakage, or impairment of their serviceability, a hydrostatic test pressure equal to that prescribed for the specified matching pipe of equivalent material.

11. Dimensions

11.1 Butt-welding fittings and butt-welding short-radius elbows and returns purchased in accordance with this specification shall conform to the dimensions and tolerances given in the latest revision of ANSI B16.9 and ANSI B16.28, respectively. Steel socket-welding and threaded fittings purchased in accordance with this specification shall conform to the sizes, shapes, dimensions, and tolerances specified in the latest revision of ANSI B16.11.

11.2 Fittings of size or shape differing from these standards, but meeting all other requirements of the specification, may be furnished in accordance with Supplementary Requirement S6.

12. Surface Quality

12.1 Fittings supplied under this specification shall be examined visually. Selected typical surface discontinuities shall be explored for depth. The fittings shall be free from surface discontinuities that penetrate more than 5% of the specified nominal wall thickness, except as defined in 12.3 and 12.4, and shall have a workmanlike finish.

12.2 Surface discontinuities deeper than 5% of the specified nominal wall thickness, except as defined in 12.3 and 12.4, shall be removed by the manufacturer by machining or grinding to sound metal, and the repaired areas shall be well faired. The wall thickness at all points shall be at least 87½% of the specified nominal wall thickness, and the diameters at all points shall be within the specified limits.

12.3 Surface checks (fish scale) deeper than $\frac{1}{64}$ in. [0.4 mm] shall be removed.

12.4 Mechanical marks deeper than $\frac{1}{16}$ in. [1.6 mm] shall be removed.

12.5 When the removal of a surface discontinuity reduces the wall thickness below 87½% of the specified nominal wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in 12.6.

12.6 *Repair by Welding (Base Metal):*

12.6.1 Repair welding, by the manufacturer, is permissible for parts made to dimensional standards such as those of ANSI or equivalent standards.

12.6.2 Prior approval of the purchaser shall be required to weld repair special parts made to the purchaser's dimensional requirements.

12.6.3 The welding procedures, welders, and welding operators shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

12.6.4 The composition of the weld deposits shall be in accordance with 7.2 and in accordance with the procedure qualification for the applicable material. Welding shall be accomplished with a weld procedure designed to produce low hydrogen in the weldment. Short circuit gas metal arc welding is permissible only with the approval of the purchaser.

12.6.5 Unacceptable imperfections shall be removed by mechanical means or thermal cutting or gouging methods. Cavities prepared for welding shall be examined by one of the following methods to verify removal of the imperfections:

12.6.5.1 Magnetic particle examination in accordance with Test Method A 275 or Practice E 709.

12.6.5.2 Liquid penetrant examination in accordance with Practice E 165.

12.6.6 The weld repair shall be permanently identified with the welder's stamp or symbol in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

12.6.7 Weld repair area(s) shall be blended uniformly to the base metal and shall be examined by the same method used in 12.6.5.

12.6.8 Repair welding shall exceed neither 10% of the surface area of the part nor 33½% of the wall thickness of the finished product at the location of the repair, without prior approval of the purchaser.

12.6.9 After weld repair, material shall be heat treated in accordance with 6.1.

12.6.10 Tension and impact testing of representative deposited weld metal for each heat shall meet the requirements of 8.2 and 9.1.

13. Radiographic Examination

13.1 All fusion-welded butt joints shall be radiographically examined throughout the entire length in accordance with Paragraph UW-51 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code. Instead of radiographic examination, welds made by the manufacturer may be ultrasonically examined in accordance with Appendix 12 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code. In general, radiography or ultrasonic examination should be performed after all forming operations have been completed. Fittings made from fusion-welded pipe need not be radiographed if the pipe has been radiographed, provided the fitting forming process does not materially affect the weld.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with this specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

14.2 Other tests, when required by agreement shall be made from materials of the lots (4) covered in the order.

15. Rejection and Rehearing

15.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

15.2 Fittings that develop defects in shop working or application operations may be rejected. Upon rejection, the manufacturer shall be notified promptly in writing.

16. Certification

16.1 When requested by the purchaser, the manufacturer shall provide a certificate of compliance to this specification. In addition, if requested to provide test reports, the manufacturer shall also provide the following where applicable:

16.1.1 Chemical analysis results, Section 7 (Table 1),

16.1.2 Tensile property results, Section 8 (Table 3) report yield strength and ultimate strength in ksi [MPa] and elongation in percent,

16.1.3 Impact test results, Section 9 (Tables 4 and 5),

16.1.4 Type heat treatment, Section 6,

16.1.5 Radiographic examination statement, Section 13, and

16.1.6 Any supplemental testing required by the purchase order.

16.2 Certification shall state whether welds have been examined radiographically or ultrasonically.

17. Product Marking

17.1 All fittings shall have the prescribed information marked on each fitting in accordance with MSS SP-25, latest revision.

17.1.1 Fittings may be marked by any method which will permanently identify the fittings and not result in sharp discontinuities. Stamping, when used, shall be done with blunt-nosed continuous or blunt-nosed interrupted dot stamps.

17.1.2 When agreed upon between the purchaser and producer, and specified in the order, the markings may be painted or stenciled on the fitting or stamped on a metal or plastic tag which shall be securely attached to the fitting.

17.2 The prescribed information for butt-welding fittings shall be: the manufacturer's name or trademark (see Note 1), material designation or grade, schedule number or nominal wall thickness designation, and the heat number or manufacturer's heat identification. Fittings containing welds that have been ultrasonically examined instead of radiography shall be marked U after heat identity.

NOTE 1 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component complies with this specification.

17.3 The prescribed information for threaded or socket welding fittings shall be: the manufacturer's name or trademark, material designation or grade, pressure class or schedule number, and size.

17.4 When size does not permit complete marking, identification marks may be omitted in the reverse order of those listed above and in accordance with MSS SP-25.

17.5 The impact test temperature shall also be shown if it is different from the standard test temperature specified in Table 6, for example: WPL-6-60 or WPL3-176.

17.6 *Bar Coding* — In addition to the requirements in 17.1, 17.2, 17.3, 17.4, and 17.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag. **98**

98

TABLE 1
CHEMICAL REQUIREMENTS

Grade[A]	Composition, %						
	C	Mn	P	S	Si	Ni	Cu
WPL6[B,C]	0.30	0.39–1.06	0.030	0.030	0.10 min	—	—
WPL9	0.20	0.40–1.06	0.030	0.030	—	1.60–2.24	0.75–1.25
WPL3[D]	0.20	0.31–0.64	0.05	0.05	0.13–0.37	3.2–3.8	—
WPL8[E]	0.13	0.90	0.030	0.030	0.13–0.37	8.4–9.6	—

[A] When fittings are of welded construction, the symbols above shall be supplemented by the letter "W".
[B] For each reduction of 0.01% carbon below 0.30%, an increase of 0.05% manganese above 1.06% will be permitted to a maximum of 1.35% manganese.
[C] Fittings made from forgings may have 1.35% max manganese.
[D] Fittings made from plate or forgings may have 0.90% max manganese.
[E] Fittings made from plate may have 0.98% max manganese.

TABLE 2
POST-WELD HEAT TREATMENT

Grade	Metal Temperature		Minimum Holding Time
	°F	°C	
WPL6	1100–1200	595–650	1 h/in. [25 mm] 3/4 h min
WPL3	1100–1150	540–620	1/4 h/in. [25 mm] 1 h min
WPL8	1050–1100	565–595	1/2 h/in. [25 mm] 1 h min
WPL9[A]	1025–1085	550–585	1 h/in. [25 mm] 2 h min

[A] 2 in. [51 mm] thickness and over. The cooling rate shall not be less than 300°F [150°C] per hour down to a temperature of 600°F [315°C].

TABLE 3
TENSILE REQUIREMENTS

Requirement	Grade			
	WPL6	WPL9	WPL3	WPL8
Tensile strength, min ksi [MPa]	60 [415]–85 [585]	63 [435]–88 [610]	65 [450]–90 [620]	100 [690]–125 [865]
Yield strength, min ksi [MPa]	35 [240]	46 [315]	35 [240]	75 [515]

Elongation Requirements	Grades							
	WPL6		WPL9		WPL3		WPL8	
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Standard round specimen, or small proportional specimen, min % in 4 D	22	12	20	. . .	22	14	16	. . .
Rectangular specimen for wall thickness $^5/_{16}$ in. [7.94 mm] and over, and for all small sizes tested in full section; min % in 2 in. or 50 mm	30	16.5	28	18	30	20	22	. . .
Rectangular specimen for wall thickness less than $^5/_{16}$ in [7.94 mm]; min % in 2 in. or 50 mm ($^1/_2$-in. [12.7-mm] wide specimen)	[A]	[A]	[A]	[A]	[A]	[A]	[A]	. . .

[A] For each $^1/_{32}$ in. [0.79 mm] decrease in wall thickness below $^5/_{16}$ in. [7.94 mm], a deduction of 1.5% (grades WPL6, WPL9, and WPL3) or 1.25% (WPL8) for longitudinal and 1.0% (grades WPL6, WPL9 and WPL3) for transverse from the values shown above is permitted. The following table gives the minimum value for various wall thicknesses:

Wall Thickness		Grades							
		WPL6		WPL9		WPL3		WPL8	
in.	[mm]	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
$^5/_{16}$ (0.312)	[7.94]	30.0	16.5	28.0	18.0	30.0	20.0	22.0	. . .
$^9/_{32}$ (0.281)	[7.14]	28.5	15.5	26.5	17.0	28.5	19.0	20.75	. . .
$^1/_4$ (0.250)	[6.35]	27.0	14.5	25.0	16.0	27.0	18.0	19.5	. . .
$^7/_{32}$ (0.219)	[5.56]	25.5	. . .	23.5	. . .	25.5	. . .	18.25	. . .
$^3/_{16}$ (0.188)	[4.76]	24.0	. . .	22.0	. . .	24.0	. . .	17.0	. . .
$^5/_{32}$ (0.156)	[3.97]	22.5	. . .	20.5	. . .	22.5	. . .	15.75	. . .
$^1/_8$ (0.125)	[3.17]	21.0	. . .	19.0	. . .	21.0	. . .	14.5	. . .
$^3/_{32}$ (0.094)	[2.38]	19.5	. . .	17.5	. . .	19.5	. . .	13.25	. . .
$^1/_{16}$ (0.062)	[1.59]	18.0	. . .	16.0	. . .	18.0	. . .	12.0	. . .

NOTE — The preceding table gives the computed minimum elongation value for each $^1/_{32}$ in. [0.79 mm] decrease in wall thickness. Where the wall thickness lies between two values above, the minimum elongation value is determined by the following equations:

Direction of Test	Equations			
	WPL6	WPL9	WPL3	WPL8
Longitudinal	$E = 48t + 15.00$	$48t + 13.00$	$E = 48t + 15.00$	$40t + 9.50$
Transverse	$t = 32t + 6.50$	$32t + 8.00$	$E = 32t + 10.00$	. . .

Where:
E = elongation in 2 in. or 50 mm, %, and
t = actual thickness of specimen, in.

TABLE 4
CHARPY IMPACT REQUIREMENTS FOR WPL6, WPL9, AND WPL3[A]

Size of Specimen, mm	Charpy V-Notch Impact Value Required for Acceptance (Average of Three Specimens)		Minimum Charpy V-Notch Impact Value Without Requiring Retest (One Specimen Only of a Set)	
	ft · lbf	J	ft · lbf	J
10 by 10.0	13	17.6	10	13.6
10 by 7.5	10	13.6	8	10.8
10 by 5.0	7	9.5	5	7.0
10 by 2.5	4	5.4	3	4.1

[A] Straight-line interpolation for intermediate values is permitted.

TABLE 5
CHARPY IMPACT REQUIREMENTS FOR WPL8

Size of Specimen, mm	Charpy V-Notch Impact Value Required for Acceptance (Average of Three Specimens)		Minimum Charpy V-Notch Impact Value Without Requiring Retest (One Specimen Only of a Set)	
	ft · lbf	J	ft · lbf	J
10 by 10.0	25.0	33.9	20.0	27.1
10 by 7.5	21.0	28.5	17.0	23.1
10 by 5.0	17.0	23.1	14.0	19.0
10 by 2.5	8.0	10.8	6.0	8.1

TABLE 6
IMPACT TEST TEMPERATURE

Grade	Impact Test Temperature, °F [°C]
WPL6	−50 [−45]
WPL9	−100 [−75]
WPL3	−150 [−100]
WPL8	−320 [−195]

SUPPLEMENTARY REQUIREMENTS FOR WELDING FITTINGS REQUIRING SPECIAL CONSIDERATION

These requirements shall not be considered unless specified in the order, in which event any of the supplementary requirements specified in following sections shall be made at the place of manufacture, unless otherwise agreed upon, at the purchaser's expense. The tests specified shall be witnessed by the purchaser's inspector before shipment of material, if so specified in the order.

S1. Product Analysis

S1.1 A product analysis shall be made from each heat of base metal and, if of welded construction, from each lot number of welding material of the fittings offered for delivery. The analysis shall conform to the requirements specified in Table 2 (Note 2).

NOTE 2 — If the results of any of the tests specified in Supplementary Requirements S1 or S2 do not conform to requirements, retests may be made at the manufacturer's expense on additional fittings or representative test pieces of double the original number from the same heat or lot as defined in Supplementary Requirement S1 or S2, each of which shall conform to the requirements specified.

S2. Tension Test

S2.1 One tension test shall be made on one fitting or representative test piece (Note 3) per lot (Note 4) of fittings. If the fittings are welded construction, the tension specimen shall include the weld and shall be prepared so that the weld is at the midlength location of the specimen.

98 NOTE 3 — Where the test specimen for the tension test cannot be taken from a fitting due to size limitations, a representative test piece shall be obtained. The test piece shall be from the same heat and heat treated in the same batch or charge as the fittings it represents and shall have approximately the same amount of working. In addition, test pieces representing fittings manufactured from bars, plates, or forgings shall have a cross-section equal to the greatest cross-section of the fitting, and test pieces representing fittings manufactured from pipe shall have an outside diameter and wall thickness equal to those of the fittings. The test piece for fittings of welded construction shall be prepared to the same weld procedures and from the same heats of materials as the fittings it represents.

NOTE 4 — *Lot* — A "lot" shall consist of all fittings of the same type, size, and wall thickness, manufactured from one heat of material (and, if welding is performed using one lot number of electrode or one heat of weld wire, and one lot number of flux), heat treated in either a continuous or batch-type furnace controlled within a range of 50°F [28°C] and equipped with recording pyrometers so that complete records of heat treatment are available.

S2.2 If the results of any of the tension tests of any lot do not conform to requirements, retests shall be made on additional fittings or representative tests pieces of double the original number from the same lots, each of which shall conform to the requirements specified.

S3. Liquid Penetrant Test

S3.1 All surfaces shall be liquid penetrant tested. The method shall be in accordance with Practice E 165. Acceptance limits shall be specified by the purchaser. Personnel performing the examination shall be qualified in accordance with SNT-TC-1A.

S4. Magnetic Particle Test

S4.1 All accessible surfaces shall be magnetic particle inspected. The method shall be in accordance with Practice E 709. Acceptance limits shall be specified by the purchaser. Personnel performing the examination shall be qualified in accordance with SNT-TC-1A.

S5. Hydrostatic Test

S5.1 A hydrostatic test shall be applied as agreed upon between the manufacturer and the purchaser.

S6. Nonstandard Fittings

S6.1 Fittings of size or shape not conforming to 98
design requirements of ANSI B16.9, B16.11, B16.28, MSS SP-79, and MSS SP-95 shall meet all other requirements of this specification. In addition to the marking required by Section 17, the grade designation symbol shall be followed by the symbol "S6".

S7. Repair Welding

S7.1 No weld repair shall be permitted without prior approval of the purchaser.

S8. Marking Small Fittings

S8.1 For small products where the space for marking is less than 1 in. [25 mm] in any direction, test reports are mandatory and marking may be restricted to only such symbols or codes as are necessary to identify the parts with test reports.

S8.2 When the configuration or size does not permit marking directly on the fitting, marking method shall be a matter of agreement between the manufacturer and the purchaser.

SPECIFICATION FOR SEAMLESS AND ELECTRIC-WELDED LOW-ALLOY STEEL TUBES

SA-423/SA-423M

(Identical with ASTM Specification A 423/A 423M-95.) 98

1. Scope

1.1 This specification covers minimum-wall-thickness, seamless and electric-resistance welded, low-alloy steel tubes for pressure containing parts such as economizers or other applications where corrosion resistance is important.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ½ to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.500 in. [0.9 to 12.7 mm] inclusive, in minimum wall thicknesses. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ¼ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 An optional supplementary requirement is provided and, when desired, shall be so stated in the order.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Document

2.1 *ASTM Standard:*

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

3. Ordering Information

3.1 Orders for material under this specification shall include the following, as required, to describe the desired material adequately;

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (seamless or electric-resistance welded tubes),

3.1.3 Grade (Table 1),

3.1.4 Manufacture (hot finished or cold finished),

3.1.5 Size (outside diameter and minimum wall thickness)

3.1.6 Length (specific or random),

3.1.7 Optional requirements (hydrostatic or electric test, 13.7),

3.1.8 Test report required (see Certification Section of Specification A 450/A 450M),

3.1.9 Specification designation, and

3.1.10 Special requirements and any supplementary requirements selected.

4. Manufacture

4.1 Tubes made by the seamless process may be hot finished or cold finished.

5. Heat Treatment

5.1 All tubes shall be normalized or given such heat treatment as may be necessary to conform to the requirements of this specification.

6. Chemical Composition

6.1 The steel shall conform to requirements as to chemical composition prescribed in Table 1.

7. Product Analysis

7.1 An analysis of either one billet, one length of flat-rolled stock or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

7.2 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock, or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 1) shall be rejected or, at the option of the producer, each billet, length of flat-rolled stock or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 1—For flattening, flaring, and flange requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

NOTE 2—For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

9. Hardness Requirements

9.1 The tubes shall have a hardness number not exceeding 170 HB or 87 HRB.

10. Forming Operations

10.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws.

11. Mechanical Tests Required

11.1 *Tension Test*—One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 2).

11.2 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring or flanging test, from each lot (Note 1).

11.3 *Flaring Test (Seamless Tubes)*—One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

11.4 *Flange Test (Welded Tubes)*—One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

11.5 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 2).

11.6 *Reverse Flattening Test*—For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

11.7 *Hydrostatic or Nondestructive Electric Test*—Each tube shall be subjected to the hydrostatic test, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

12. General Requirements

12.1 Material furnished under this specification should conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include whether hot finished or cold finished, and whether seamless or welded.

14. Keywords

14.1 Seamless steel tube; steel tube; alloy; welded steel tube

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %	
	Grade 1	Grade 2
Carbon, max	0.15	0.15
Manganese, max	0.55	0.50–1.00
Phosphorus	0.06–0.16	0.04 max
Sulfur, max	0.060	0.05
Silicon, min	0.10	. . .
Copper	0.20–0.60	0.30–1.00
Chromium	0.24–1.31	. . .
Nickel	0.20–0.70	0.40–1.10
Molybdenum, min	. . .	0.10

TABLE 2
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

Tensile strength, min, ksi [MPa]	60 [415]
Yield strength, min, or 50 mm, ksi [MPa]	37 [255]
Elongation in 2 in. or 50 mm, min, %	25
For longitudinal strip tests a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{3}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points shall be made	1.25[A]

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order. Details of this supplemental requirement shall be agreed upon by the manufacturer and the purchaser.

S1. Surface Condition

S1.1 If pickling or shot-blasting, or both, are required, this shall be specifically stated in the order and shall be done at the purchaser's expense.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered unless specified in the order and the necessary tests shall be made at the mill.

S2. Additional Testing of Welded Tubing per ASME Request

S2.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 450/A 450M.

S2.2 If Practice E 273 is employed, a 100% volumetric inspection of the entire length of each tube shall also be performed using one of the non-destructive electric tests permitted by Specification A 450/A 450M.

S2.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S2.4 In addition to the marking prescribed in Specification A 450/A 450M, "S2" shall be added after the grade designation.

SPECIFICATION FOR CENTRIFUGALLY CAST FERRITIC ALLOY STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

SA-426

(Identical with ASTM Specification A 426-92 except for deletion of grade CP7 in Table 3.)

1. Scope

1.1 This specification covers centrifugally cast alloy steel pipe intended for use in high-temperature, high-pressure service.

1.2 Several grades of ferritic steels are covered. Their compositions are given in Table 1.

1.3 Supplementary requirements (Sections S1 through S12) are provided. The supplementary requirements provide for additional tests of an optional nature and when desired shall be so stated in the order (Section 4).

1.4 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
A 609/A 609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof
E 44 Definitions of Terms Relating to Heat Treatment of Metals
E 94 Guide for Radiographic Testing
E 165 Practice for Liquid Penetrant Inspection Method
E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. [51 to 114-mm] Steel Castings
E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels
E 280 Reference Radiographs for Heavy-Walled [4½ to 12-in. [114 to 305-mm] Steel Castings
E 446 Reference Radiographs for Steel Castings Up to 2 in. [51 mm] in Thickness
E 709 Practice for Magnetic Particle Examination

2.2 *ANSI Standard:*

B46.1 Surface Texture

2.3 *ASME Boiler and Pressure Vessel Code:*

Section IX Welding Qualifications

3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification shall include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, centimetres, or number of lengths),

4.1.2 Name of material (centrifugally cast pipe),

4.1.3 Specification number,

4.1.4 Grade (Table 1),

4.1.5 Size (outside or inside diameter and minimum wall thickness),

4.1.6 Length (specific or random) (Section on Permissible Variation in Length of Specification A 530/A 530M),

4.1.7 End finish (Section on Ends of Specification A 530/A 530M),

4.1.8 Optional Requirements (S1 through S12) Section 13.1,

4.1.9 Test report required (Section on Certification of Specification A 530/A 530M),

4.1.10 Service temperature if over 1000°F [540°C] (Note), and

4.1.11 Special requirements or additions to specification.

5. Materials and Manufacture

5.1 *Heat-Treatment*—The pipe shall be furnished in the normalized and tempered or liquid-drenched and tempered condition (Note). The temperature for tempering shall not be less than 1250°F [677°C] except for Grades CP1, CP2, CP11, CP12, and CP15 for which the temperature for tempering shall not be less than 1100°F [595°C].

5.1.1 Heat treatment shall be performed after the pipe has been allowed to cool below the transformation range. Definition of heat-treatment terms shall be as given in Definitions E 44.

NOTE—It is recommended that the temperature for tempering should be at least 100°F [56°C] above, the intended service temperature. The purchaser shall advise the manufacturer of the service temperature when it is over 1000°F [540°C].

5.2 *Machining*—The pipe shall be machined on the inner and outer surfaces to a roughness value no greater than 250 μin. [6.35 μm] arithmetical average deviation (AA) from the mean line unless otherwise specified as in B46.1

6. Chemical Analysis

6.1 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of elements specified in Table 1. The analysis shall be made on a test sample taken preferably during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1.

6.2 *Product Analysis*—A product analysis may be made by the purchaser. The sample for analysis shall be selected so as to be representative of the pipe being analyzed. The chemical composition thus determined shall conform to the requirements of Table 1.

7. Tensile and Hardness Requirements

7.1 Steel used for the castings shall conform to the tensile and hardness requirements specified in Table 2.

8. Test Specimens

8.1 Test coupons from which tension test specimens are prepared shall be removed from heat-treated casting prolongations.

8.2 When agreed upon between the manufacturer and the purchaser, test coupons from which test specimens are prepared shall be cast attached to separate blocks from the same heat as the casting represented. The test blocks shall be heat treated in the same manner as the casting represented.

8.3 Tension test specimens shall be machined to the form and dimensions on the standard round 2 in. [50 mm] gage length specimens shown in Fig. 6 of Test Methods and Definitions A 370.

9. Number of Tests

9.1 One tension and one hardness test shall be made from each heat.

9.2 If a specimen is machined improperly or if flaws are revealed by machining or during testing, the specimen may be discarded and another substituted from the same heat.

10. Retests

10.1 If the results of the mechanical tests for any heat do not conform to the requirements specified, the castings may be reheat-treated and retested, but may not be re-austenitized more than twice.

11. Hydrostatic Test

11.1 Each length of pipe shall be hydrostatically tested in accordance with Specification A 530/A 530M.

11.2 When agreed to between the manufacturer and the purchaser and so stated in the order, the hydrostatic test may be deferred and shall be performed later by the purchaser. Pipe furnished without the hydrostatic test shall include with the mandatory marking the letters "NH". The manufacturer is responsible for the satisfactory performance of the casting when it is tested.

11.3 When certification is required by the purchaser and the hydrostatic test has been omitted, the certification shall clearly state "not hydrostatically tested". The specification number and material grade shown on the certification shall be followed by the letters "NH".

12. Visual Inspection

12.1 The surface of the casting shall be free from cracks and hot tears as determined by visual examination. Other surface imperfections shall be judged in accordance with visual acceptance criteria which may be specified in the order.

13. Rework and Retreatment

13.1 Defects as defined in Section 13 shall be removed and their removal verified by visual inspection of the resultant cavities. Defects that are located by inspecting with supplementary requirements S6, S7, S8, or S9 shall be removed or reduced to an acceptable size.

13.2 If removal of the defect does not infringe upon the minimum wall thickness, the depression may be blended uniformly into the surrounding surface.

13.3 If the cavity resulting from defect removal infringes upon the minimum wall thickness, weld repair is permitted subject to the purchaser's approval. The composition of the weld rod used shall be suitable for the composition of the metal being welded.

13.3.1 Only welders and procedures qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX, shall be used. All repair welds will be inspected to the same quality standards used to inspect the casting.

14. Permissible Variations in Dimensions

14.1 *Thickness*—The wall thickness shall not vary over that specified by more than $\frac{1}{8}$ in. [3 mm]. There shall be no variation under the specified wall thickness.

15. Rejection

15.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of a specification based on the inspection and test method as outlined in the specification, the pipe may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

16. Product Marking

16.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the specification number and grade. In addition, heat numbers or serial numbers that are traceable to heat numbers shall be marked on each length of pipe.

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %						
Grade	Carbon	Man-ganese	Phospho-rus, max	Sulfur, max	Silicon	Chromium	Molybdenum
CP1	0.25 max	0.30–0.80	0.040	0.045	0.10–0.50	. . .	0.44–0.65
CP2	0.10–0.20	0.30–0.61	0.040	0.045	0.10–0.50	0.50–0.81	0.44–0.65
CP5	0.20 max	0.30–0.70	0.040	0.045	0.75 max	4.00–6.50	0.45–0.65
CP5b	0.15 max	0.30–0.60	0.040	0.045	1.00–2.00	4.00–6.00	0.45–0.65
CP9	0.20 max	0.30–0.65	0.040	0.045	0.25–1.00	8.00–10.00	0.90–1.20
CP11	0.05–0.20	0.30–0.80	0.040	0.045	0.60 max	1.00–1.50	0.44–0.65
CP12	0.05–0.15	0.30–0.61	0.040	0.045	0.50 max	0.80–1.25	0.44–0.65
CP15	0.15 max	0.30–0.60	0.040	0.045	0.15–1.65	. . .	0.44–0.65
CP21	0.05–0.15	0.30–0.60	0.040	0.045	0.50 max	2.65–3.35	0.80–1.06
CP22	0.05–0.15	0.30–0.70	0.040	0.045	0.60 max	2.00–2.75	0.90–1.20
CPCA15	0.15 max	1.00 max	0.040	0.040	1.50 max	11.5–14.0	0.50 max

TABLE 2
TENSILE PROPERTIES AND HARDNESS REQUIREMENTS

Tensile strength, min, psi (MPa):	
Grade CP1	65 000 (450)
Grades CP11, CP22	70 000 (485)
Grades CP5, CP9, CPCA15	90 000 (620)
All other grades	60 000 (415)
Yield strength, min, psi (MPa):	
Grade CP1	35 000 (240)
Grades CP11, CP22	40 000 (275)
Grades CP5, CP9	60 000 (415)
Grade CPCA15	65 000 (450)
All other grades	30 000 (205)
Elongation, min, %:[A]	
Grade CP1	24
Grades CP11, CP22	20
Grades CP5, CP9, CPCA15	18
All other grades	22
Reduction of area, min, %:	
Grades, CP1, CP2, CP11, CP12, CP15, CP21, CP22, CP5, CP5b, CP7, CP9	35
Grade CPCA15	30
Hardness, max, HB:	
Grades CP5, CP5b, CP9, CPCA15	225
All other grades	201

[A] Elongation in 2 in. (50 mm) using a standard round specimen, in either the transverse or longitudinal direction.

TABLE 3
RESIDUAL ELEMENTS

Grade	Copper, max	Nickel, max	Chromium, max	Tungsten, max	Total Contents of These Unspecified Elements, max, %
CP1	0.50	0.50	0.35	0.10	1.00
CP2	0.50	0.50	. . .	0.10	1.00
CP5	0.50	0.50	. . .	0.10	1.00
CP5b	0.50	0.50	. . .	0.10	1.00
CP9	0.50	0.50	. . .	0.10	1.00
CP11	0.50	0.50	. . .	0.10	1.00
CP12	0.50	0.50	. . .	0.10	1.00
CP15	0.50	0.50	0.35	0.10	1.00
CP21	0.50	0.50	. . .	0.10	1.00
CP22	0.50	0.50	. . .	0.10	1.00
CPCA15	0.50	1.00	. . .	0.10	1.50

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon between the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Additional Tension Tests

S1.1 Additional tension tests shall be made at a temperature to be specified by the customer, and the properties to be met are a matter of agreement between the purchaser and manufacturer.

S2. Flattening Test

S2.1 The flattening test shall be made on specimens from one or both ends of each length of pipe. If the specimen from any end of any length fails to conform to the requirements of Specification A 530/A 530M, that length shall be rejected.

S3. Photomicrographs

S3.1 The manufacturer shall furnish one photomicrograph at 100 diameters from one specimen of as-finished pipe from each heat in each heat-treatment lot. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. Such photomicrographs are for information only, to show the actual metal structure of the pipe as furnished. No photomicrographs for the individual pieces furnished shall be required except as specified in Section S4.

S4. Photomicrographs for Individual Pieces

S4.1 The manufacturer shall furnish photomicrographs from one or both ends of each pipe. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S5. Metal Structure and Etching Tests

S5.1 Etching tests shall be made on transverse sections from the pipe and shall reveal the macrostructure of the material. Such tests are for information only.

S6. Radiographic Examination

S6.1 The castings shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with Guide E 94 and the types and degrees of discontinuities considered shall be judged by Reference Radiographs E 186, E 280, or E 446. The extent of the examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S7. Liquid Penetrant Examination

S7.1 The castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The method of performing the liquid penetrant test shall be in accordance with Practice E 165. The areas to be inspected, the methods and types of liquid penetrants to be used, the developing procedure, and the basis for acceptance shall be as specified on the inquiry or invitation to bid and on the purchase order or contract or both, as agreed upon between the manufacturer and purchaser.

S8. Magnetic Particle Inspection

S8.1 The castings shall be examined by magnetic particle inspection. The inspection procedure used shall be in accordance with Practice E 709. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S9. Ultrasonic Inspection

S9.1 The castings shall be examined ultrasonically in accordance with Practice A 609/A 609 M. The extent of the examination and the basis of acceptance shall be subject to agreement between the manufacturer and the purchaser.

S10. Residual Elements

S10.1 An analysis for the elements specified in Table 3 shall be included in those analyses specified in Section 6. The chemical composition thus determined shall conform to the requirements of Table 3.

S11. Charpy Impact Test

S11.1 Charpy impact test properties shall be determined on each heat from a set of three Charpy V-notch specimens. The test coupons shall be taken as specified for tension specimens in Section 8 and tested at a test temperature agreed upon by the manufacturer and purchaser. The acceptance requirements shall be either energy absorbed or lateral expansion or percent shear area, and shall be that agreed upon by the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S11.2 *Absorbed Energy Value,* of three specimens shall not be less than that agreed upon by the manufacturer and purchaser, with no more than one value permitted below the minimum average specified and no value permitted below the minimum specified for a single specimen.

S11.3 *Lateral Expansion Value,* shall be agreed upon by the manufacturer and purchaser.

S11.4 *Perfect Shear Area,* shall be agreed upon by the manufacturer and purchaser.

S12. Drop Weight Test

S12.1 Drop weight test properties shall be determined by preparing and testing either Type P1, P2, or P3 specimens in accordance with Test Methods E 208. The test coupons shall be taken as specified for tension specimens in Section 8. The crack starter weld shall be deposited on the surface of the specimen which was nearest to the casting surface. Each test shall consist of at least two specimens tested at a temperature agreed upon by the manufacturer and purchaser. Each specimen shall exhibit a “no break” performance.

SPECIFICATION FOR AUSTENITIC STEEL FORGED AND BORED PIPE FOR HIGH-TEMPERATURE SERVICE

SA-430/SA-430M

(Identical with ASTM Specification A 430/A 430M-91 except for clarified heat treatment requirements in 5.4.1.) 98

1. Scope

1.1 This specification covers heavy-wall, forged and bored austenitic steel pipe (Note 1), intended primarily for high-temperature central station service. Pipe ordered to this specification shall be suitable for bending and other forming operations and for fusion welding. Selection will depend on design, service conditions, mechanical properties and high-temperature characteristics. The "H" grades and nitrogen grades (304N and 316N) are specifically intended for high-temperature service.

NOTE 1 — The use of the word "pipe" throughout the several sections of this specification is used in the broad sense and intended to mean pipe, headers, or leads.

1.2 Eleven grades of austenitic steels are covered. Their compositions are given in Table 1.

1.3 Optional supplementary requirements (S1 through S11) are provided. These sections call for additional tests to be made, and when desired shall be so stated in the order, together with the number of such tests required.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 2 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

2.2 *ANSI Standard:*

B46.1 Surface Texture

3. General Requirements

3.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material to this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, centimeters, or number of lengths),

4.1.2 Name of material (forged and bored pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (outside diameter and minimum wall thickness),

4.1.5 Length (specific or random) (Permissible Variations in Length Section of Specification A530/A 530M),

4.1.6 End finish (Section 10),

4.1.7 Special surface finish (see 5.3),

4.1.8 Optional requirements (see 5.4.2, Section 7, and Supplementary Requirements S1 to S11),

4.1.9 Test report required (see Certification Section of Specification A 530/A 530M),

4.1.10 Specification designation, and

4.1.11 Special requirements or exceptions to specification.

98 5. Materials and Manufacture

5.1 *Discard* — A sufficient discard shall be made from each ingot to secure freedom from injurious defects and undue segregation.

5.2 *Manufacturing Practice:*

5.2.1 Material for forgings shall consist of ingots, or of blooms, slabs, or bars either forged or rolled from an ingot, and cut to the required length by a process that will not produce injurious defects in the forging.

5.2.2 The material shall be forged by hammering, pressing, rolling, or extruding, and shall be brought as nearly as practicable to the finished shape and size by hot working. The material shall be adequately worked under a tool of sufficient capacity to refine the structure in the wall of the finished pipe.

5.3 *Machining:*

5.3.1 All forgings shall have both the inner and outer surfaces machined.

5.3.2 After heat treatment, the pipe shall be machined to a finish with a roughness value no greater than 250 μin. [6.4 μm] arithmetical average deviation (AA), terms as defined in ANSI B46.1, unless otherwise specified.

5.4 *Heat Treatment:*

5.4.1 All pipe shall be furnished in the solution-treated condition unless the order specifically states that no final heat treatment shall be applied. For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. When the order is furnished without final heat treatment, each pipe shall be stenciled "HT-O". The purchaser shall have the responsibility for completing the heat-treatment requirement.

5.4.2 Unless otherwise stated in the order, heat treatment shall consist of heating Types FP 321H and FP 347H to a minimum temperature of 1925°F [1050°C]; Type FP 16-8-2H to a minimum temperature of 1800°F [980°C]; and all other grades to minimum temperature of 1900°F [1040°C], and quenching in water or rapidly cooling by other means.

5.4.3 Solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP321, TP321H, TP347, and TP347H. When specified by the purchaser, a lower temperature stabilization or resolution anneal shall be used subsequent to the initial high temperature solution anneal (See Supplementary Requirement S10).

5.4.4 The purchaser may specify controlled structural or special service characteristics which shall be used as a guide for the most suitable heat treatment. If the final heat treatment is at a temperature other than that given in 5.4.2, each pipe shall be stenciled with the final heat treatment temperature in degrees Fahrenheit or degrees Celsius after the suffix "HT". For "H-Grade" Code materials, this heat treatment, if at a lower temperature than specified in 5.4.2, shall be applied following the heat treatment in 5.4.2.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Product Analysis

7.1 At the request of the purchaser, a product analysis of each heat or of two pipes from each lot (Note 3) shall be made by the manufacturer. A lot of pipe shall consist of the following:

NPS Designator	Number of Lengths of Pipe in Lot
Under NPS 2	400 or fraction thereof
NPS 2 to NPS 5, incl	200 or fraction thereof
NPS 5 and over	100 or fraction thereof

NOTE 3—A lot shall consist of the number of lengths specified in 7.1, of the same size and wall thickness from any one heat of steel.

7.2 The results of these analyses shall be reported to the purchaser or his representative, and shall not vary from the requirements specified in Table 1 by more than the amounts prescribed in Table 2.

7.3 If the analysis of any of the tests specified in this section does not conform to the requirements specified, an analysis of each pipe from the same heat or lot may be made, and all pipe conforming to the requirements shall be accepted.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

8.2 Tests for acceptance shall be made after final heat treatment of the pipe.

9. Workmanship

9.1 The pipe shall conform to the sizes and shapes specified by the purchaser.

10. Ends

10.1 Pipe ends shall be machined as specified in the purchase order.

11. Finish

11.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to assure compliance with 11.2.

11.2 Surface imperfections that penetrate more than $12\frac{1}{2}$% of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

11.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

11.2.2 Repaired in accordance with the repair welding provisions of 11.6.

11.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

11.2.4 Rejected.

11.3 To provide a workmanlike finish and basis for evaluating conformance with 11.2, the pipe manufacturer shall remove by grinding the following:

11.3.1 Mechanical marks, abrasions, and pits, any of which imperfections are deeper than $\frac{1}{16}$ in. [1.6 mm].

11.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears or slivers found by exploration in accordance with 11.1 to be deeper than 5% of the nominal wall thickness.

11.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 11.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

11.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

11.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

11.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

11.7 The finished pipe shall be reasonably straight.

12. Mechanical Tests Required

12.1 *Transverse of Longitudinal Tension Test*—One test shall be made on a specimen from one end of one length of pipe representing each heat in each heat-treatment lot.

12.2 *Flattening Test*—A test shall be made on specimens from one end of each length of pipe.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include the length, hydrostatic test pressure (when so tested), the marking requirements of 5.4, and an additional symbol "S" if the pipe conforms to the supplementary requirements specified in S1 to S10, the heat number or manufacturer's number by which the heat can be identified. On pipe sizes larger than NPS 4, the weight shall be given.

13.2 No steel indentation stamping shall be done without the consent of the purchaser.

TABLE 1
CHEMICAL REQUIREMENTS

Grade	FP304 or FP304H	FP304N	FP316 or FP316H	FP316N	FP321 or FP321H	FP347 or FP347H	FP16-8-2H
Element	Composition, %						
Carbon	0.04–0.10	0.04–0.10	0.04–0.10	0.04–0.10	0.04–0.10	0.04–0.10	0.05–0.10
Manganese, max	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Phosphorus, max	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Sulfur, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Silicon, max	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Nickel	8.00–11.0	8.00–11.0	11.00–14.0	11.00–14.0	9.00–13.0	9.00–13.0	7.50–9.50
Chromium	18.0–20.0	18.0–20.0	16.0–18.0	16.0–18.0	17.0–20.0	17.0–20.0	14.5–16.5
Molybdenum	. . .	. . .	2.00–3.00	2.00–3.00	. . .	. . .	1.5–2.0
Titanium	. . .	. . .	. . .	. . .	[A]	. . .	. . .
Columbium	. . .	. . .	. . .	. . .	. . .	[B]	. . .
Nitrogen[C]	. . .	0.10–0.16	. . .	0.10–0.16	. . .	. . .	. . .

[A] The titanium content shall be not less than four times the carbon content and not more than 0.60%.
[B] The columbium content shall be not less than eight times the carbon content and not more than 1.00%.
[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

TABLE 2
PERMISSIBLE VARIATIONS IN PRODUCT ANALYSIS

Elements	Limit, or Maximum of Specified Element, %	Permissible Variations, Over the Maximum Limit or Under the Minimum Limit, %
Carbon	. . .	0.0
Manganese	. . .	0.04
Phosphorus	. . .	0.005
Sulfur	. . .	0.005
Silicon	. . .	0.05
Nickel	Over 5.00 to 10.00 incl	0.10
	Over 10.00 to 20.00 incl	0.15
Chromium	. . .	0.20
Molybdenum	. . .	0.10
Titanium	. . .	0.0
Columbium	. . .	0.0

TABLE 3
TENSILE REQUIREMENTS[A]

	All Grades	
	ksi	MPa
Tensile strength, min	70	485
Yield strength, min	30	205
	Longitudinal	**Transverse**
Elongation in 2 in. or 50 mm, min, %	45	20
Reduction of area, min, %	50	30

[A] For grades FP304N and FP316N the minimum tensile strength shall be 75 000 psi [550 MPa] and the minimum yield strength shall be 35 000 psi [240 MPa].

SUPPLEMENTARY REQUIREMENTS FOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Photomicrographs

S5.1 Photomicrographs at 100 diameters may be made from one end of each piece of pipe furnished in sizes 6 in. [152 mm] and larger in the as-furnished condition. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, piece number, and heat. Such photomicrographs are for information only, and shall show the actual metal structure of the pipe as finished.

S6. Ultrasonic Testing

S6.1 Each piece of pipe may be ultrasonically tested to determine its soundness throughout the entire length of the pipe. Each pipe shall be ultrasonically tested in a circumferential direction in such a manner that the entire piece is scanned by the ultrasonic beam. The calibration standard shall be prepared from a section of pipe which has two notches, one in the inside surface and one in the outside surface. The notches shall be at least $1\frac{1}{2}$ in. [38 mm] long and have a depth of 3% of the wall thickness, or 0.004 in. [0.1 mm], whichever is greater. Any pipe showing an ultrasonic indication of greater amplitude than the amplitude of the indication from the calibration standard shall be subject to rejection.

S7. Hot Ductility Tests (Weldability Tests)

S7.1 A high-temperature ductility test may be made upon each heat of material supplied in heavy-wall pipe sections. An appropriate specimen shall be heated to an initial temperature, cooled 100°F [50°C], then subjected to a tensile test, and shall show a minimum reduction of area of 60%. The initial temperature is that temperature 50°F [30°C] below the temperature at which material exhibits zero ductility. Rejection of material shall not be based upon this test.

S8. Hydrostatic Test

S8.1 A hydrostatic test shall be applied as agreed upon by the manufacturer and purchaser.

S9. Retests

S9.1 Upon the purchaser's request, retests shall be made from sections of material removed from any part of the pipe. Failure to meet the requirements stated in the body of this specification shall be cause for rejection.

S10. Stabilization Heat Treatment

S10.1 Subsequent to the solution anneal required is 5.4, Grades TP321, TP321H, TP347, and TP347H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S11. Intergranular Corrosion Test

S11.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE 3—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S11.2 A stabilization heat treatment in accordance with Supplementary Requirement S10 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

SPECIFICATION FOR STRAIGHT-BEAM ULTRASONIC EXAMINATION OF STEEL PLATES

SA-435/SA-435M

(Identical with ASTM Specification A435/A 435M-90.) 98

1. Scope

1.1 This specification covers the procedure and acceptance standards for straight-beam, pulse-echo, ultrasonic examination of rolled fully killed carbon and alloy steel plates, ½ in [12.5 mm] and over in thickness. It was developed to assure delivery of steel plates free of gross internal discontinuities such as pipe, ruptures, or laminations and is to be used whenever the inquiry, contract, order, or specification states that the plates are to be subjected to ultrasonic examination.

1.2 Individuals performing examinations in accordance with this specification shall be qualified and certified in accordance with the requirements of the latest edition of ASNT SNT-TC-1A or an equivalent accepted standard. An equivalent standard is one which covers the qualification and certification of ultrasonic nondestructive examination candidates and which is acceptable to the purchaser.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents, therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Document

2.1 *ASNT Standard:*
SNT-TC-1A

3. Apparatus

3.1 The manufacturer shall furnish suitable ultrasonic equipment and qualified personnel necessary for performing the test. The equipment shall be of the pulse-echo straight beam type. The transducer is normally 1 to 1⅛ in. [25 to 30 mm] in diameter or 1 in. [25 mm] square; however, any transducer having a minimum active area of 0.7 in.^{2} [450 mm^2] may be used. The test shall be performed by one of the following methods: direct contact, immersion, or liquid column coupling.

3.2 Other search units may be used for evaluating and pinpointing indications.

4. Test Conditions

4.1 Conduct the examination in an area free of operations that interfere with proper functioning of the equipment.

4.2 Clean and smooth the plate surface sufficiently to maintain a reference back reflection from the opposite side of the plate at least 50% of the full scale during scanning.

4.3 The surface of plates inspected by this method may be expected to contain a residue of oil or rust or both. Any specified identification which is removed when grinding to achieve proper surface smoothness shall be restored.

5. Procedure

5.1 Ultrasonic examination shall be made on either major surface of the plate. Acceptance of defects in close proximity may require inspection from the second major surface. Plates ordered in the quenched and tempered condition shall be tested following heat treatment.

5.2 A nominal test frequency of 2¼ MHz is recommended. Thickness, grain size, or microstructure of the material and nature of the equipment or method may require a higher or lower test frequency. However, frequencies less than 1 MHz may be used only on agreement with the purchaser. A clear, easily interpreted trace pattern should be produced during the examination.

5.3 Conduct the examination with a test frequency and instrument adjustment that will produce a minimum 50 to a maximum 75% of full scale reference back reflection from the opposite side of a sound area of the plate. While calibrating the instrument, sweep the crystal along the plate surface for a distance of at least 1*T* or 6 in. [150 mm], whichever is the greater, and note the position of the back reflection. A shift in location of the back reflection during calibration shall be cause for recalibration of the instrument.

5.4 Scanning shall be continuous along perpendicular grid lines on nominal 9 in. [225 mm] centers, or at the manufacturer's option, shall be continuous along parallel paths, transverse to the major plate axis, on nominal 4 in. [100 mm] centers, or shall be continuous along parallel paths parallel to the major plate axis, on 3 in. [75 mm] or smaller centers. A suitable couplant such as water, soluble oil, or glycerin, shall be used.

5.5 Scanning lines shall be measured from the center or one corner of the plate. An additional path shall be scanned within 2 in. [50 mm] of all edges of the plate on the scanning surface.

5.6 Where grid scanning is performed and complete loss of back reflection accompanied by continuous indications is detected along a given grid line, the entire surface area of the squares adjacent to this indication shall be scanned continuously. Where parallel path scanning is performed and complete loss of back reflection accompanied by continuous indications is detected, the entire surface area of a 9 by 9 in. [225 by 225 mm] square centered on this indication shall be scanned continuously. The true boundaries where this condition exists shall be established in either method by the following technique: Move the transducer away from the center of the discontinuity until the heights of the back reflection and discontinuity indications are equal. Mark the plate at a point equivalent to the center of the transducer. Repeat the operation to establish the boundary.

6. Acceptance Standards

6.1 Any discontinuity indication causing a total loss of back reflection which cannot be contained within a circle, the diameter of which is 3 in. [75 mm] or one half of the plate thickness, whichever is greater, is unacceptable.

6.2 The manufacturer reserves the right to discuss rejectable ultrasonically tested plates with the purchaser with the object of possible repair of the ultrasonically indicated defect before rejection of the plate.

6.3 The purchaser's representative may witness the test.

7. Marking

7.1 Plates accepted in accordance with this specification shall be identified by stamping or stenciling UT 435 adjacent to marking required by the material specification.

SUPPLEMENTARY REQUIREMENTS

The following shall apply only if specified in the order:

S1. Instead of the scanning procedure specified by 5.4 and 5.5, and as agreed upon between manufacturer and purchaser, 100% of one major plate surface shall be scanned. Scanning shall be continuous along parallel paths, transverse or parallel to the major plate axis, with not less than 10% overlap between each path.

SPECIFICATION FOR ALLOY-STEEL TURBINE-TYPE BOLTING MATERIAL SPECIALLY HEAT TREATED FOR HIGH-TEMPERATURE SERVICE

SA-437/SA-437M

(Identical with ASTM Specification A 437/A 437M-94.) 98

1. Scope

1.1 This specification covers alloy-steel bolting material specially heat treated for high-temperature service, such as steam turbine, gas turbine, and similar uses. This material requires special processing and should not be used in general-purpose applications. The term "bolting material," as used in this specification, covers rolled or forged bars, bolts, nuts, screws, washers, studs, and stud bolts. The bars shall be hot wrought. The material may be further processed by centerless grinding or by cold drawing.

1.2 The high-temperature properties of the material covered by this specification are dependent upon special heat treatment, which is required. Although the high-temperature properties are not specified, they are implied by control of the chemistry, heat treatment, and room-temperature properties of the material.

NOTE 1—High-temperature tests shall not be required, unless made a matter of agreement between the manufacturer and the purchaser.

1.3 Three levels of bolting strength are covered, designated Grades B4B, B4C, and B4D. Selection will depend on the design and the stresses and service for which the product is to be used.

NOTE 2—Bolting material is also covered by the following ASTM Specifications: A 193/A 193M, A 307, A 320/A 320M, A 325, and A 354. Reference should be made to these specifications for grades of carbon- and alloy-steel bolting material for use at temperatures lower than the range intended for the material covered in this specification.

NOTE 3—When ordering material under this specification, or when incorporating this specification as a reference in any individual specification, the purchaser must designate the steel by identification symbol or analysis, or both, and definitely specify the minimum mechanical properties required as selected from Table 1.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 Psi Tensile Strength

A 320/A 320M Specification for Alloy-Steel Bolting Materials for Low-Temperature Service

A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

E 8 Test Methods of Tension Testing of Metallic Materials

2.2 *American National Standards Institute Standards:*
B1.1 Unified Screw Threads
B18.2 Square and Hexagon Bolts and Nuts

98 **2.3** *AIAG Standard:*
AIAG B-5 2.00 Primary Metals Identification Tag Application Standard

3. Ordering Information

3.1 The inquiry and order should indicate the following:

3.1.1 Specification designation, grade and class, issue date and revision letter,

3.1.2 Quantity (weight or number of pieces),

3.1.3 Description (bars, bolts, nuts, etc.),

3.1.4 Dimensions,

3.1.5 Finish (see 14.1),

3.1.6 Impact testing of nuts, if required (see Section 15),

3.1.7 Certification, if required (see 17.2), and

3.1.8 Supplementary requirements, if any.

4. Process

4.1 The steel shall be made by the electric-furnace process, unless otherwise agreed upon between the manufacturer and the purchaser.

5. Discard

5.1 A sufficient discard shall be made from each ingot to ensure freedom from injurious piping and undue segregation.

6. Heat Treatment

6.1 The material Grades B4B and B4C shall be heated to a temperature range of 1875 to 1925°F [1025 to 1050°C] and liquid quenched to below 600°F [316°C]. The material Grades B4B and B4C shall then be uniformly reheated for tempering at a tempering temperature at least 100°F [55°C] higher than the proposed operating temperature but not less than 1150°F [620°C], then air or furnace cooled to room temperature. The material shall be at the tempering temperature for a minimum of 2 hr. Double tempering may be used to enhance properties.

6.2 Material Grade B4D shall be heated to a temperature range of 1700 to 1750°F [925 to 954°C] and oil quenched. The material shall then be uniformly reheated or tempered at a temperature of 1200°F [650°C] minimum, followed by air or furnace cooling to room temperature.

6.3 Stress relieving treatment of the bar material is required after any stretcher, roller, or rotary-straightening or cold-finishing operations performed after heat treatment for mechanical properties. Local gagging or press straightening to correct camber limitations in excess of $\frac{1}{4}$ in. in any 5 ft [6 mm in any 1.5 m] shall be followed by a stress relieving heat treatment. The minimum stress relieving temperature shall be 100°F [55°C] below the minimum tempering temperature as shown in 6.1 for Grades B4B and B4C or in 6.2 for Grade B4D.

7. Chemical Composition

7.1 The material shall conform to the requirements as to chemical composition specified in Table 2.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Table 2. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Table 2.

9. Product Analysis

9.1 An analysis may be made by the purchaser from samples representing the bolting material. The chemical composition thus determined shall conform to the requirements for product variation as specified in Table 2.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties prescribed in Table 1 at room temperature after heat treatment.

10.2 The tension test specimen shall be machined to the form and dimensions prescribed in the latest issue of Test Methods and Definitions A 370. The longitudinal axis of the test specimen shall be parallel to the direction of rolling.

10.3 The "offset method" of determining yield strength as described in Test Methods E 8, shall be followed. The tensile strength shall be determined at a crosshead speed not to exceed 1½ in. [38.1 mm]/min.

11. Impact Requirements

11.1 The material Grades B4B, B4C, and B4D shall conform to the requirements as to impact properties prescribed in Table 3 at room temperature after heat treatment.

11.2 The impact test specimen shall be the Charpy type, milled V-notch, and shall conform in all respects with the specimen shown in Fig. 10 of Test Methods and Definitions A 370. The longitudinal axis of the specimen shall be parallel to the direction of rolling.

12. Hardness Tests

12.1 The material Grades B4B, B4C, and B4D shall conform to the requirements as to hardness as prescribed in Table 4 at room temperature after heat treatment.

12.2 The hardness tests shall be conducted in accordance with Annex A3.4 of Test Methods and Definitions A 370.

13. Number of Tests

13.1 For heat-treated bars, one tension test and one impact test, consisting of three specimens, shall be made on each of two bars of each diameter of each heat in each tempering charge. For purposes of the tension and impact tests on heat-treated bars, the diameter range shall be in increments of ½ in. [12.5 mm], for example, ½ to 1 in. [12.5 to 25 mm], 1 to 1½ in. [25 to 38 mm], etc.

13.2 For studs, bolts, screws, etc., one tension test and one impact test, consisting of three specimens, shall be made for each diameter of each heat involved in the lot. Each lot shall consist of the following:

Diameter, in. [mm]	Lot Size
1½ [38] and under	200 lb [90 kg] or fraction thereof
Over 1½ to 1¾ [45] incl	400 lb [180 kg] or fraction thereof
Over 1¾ to 2½ [65] incl	600 lb [270 kg] or fraction thereof
Over 2½	20 pieces or fraction thereof

13.3 Tension and impact tests are not required to be made on bolts, screws, studs, or stud bolts which are fabricated from heat-treated bars furnished in accordance with the requirements of this specification and tested in accordance with 13.1, provided they are not given a subsequent heat treatment.

13.4 For nuts and washers, hardness tests shall be made on samples from each lot, a lot consisting of all nuts or washers of one nominal size and one nominal thickness from the same heat offered for inspection at one time. The number of samples in each lot shall be as follows:

Number of Pieces in Lot	Number of Samples
800 and under	1
801 to 8000	2
8001 to 22 000	3
Over 22 000	5

14. Retests

14.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may reaustenitize and quench such lot not more than once, in which case a double test sample shall be taken from each lot, all of which shall conform to the requirements specified.

15. Workmanship, Finish, and Appearance

15.1 Bolts, nuts, screws, studs and stud bolts shall have a finish as agreed upon by manufacturer and purchaser.

15.2 Standard permissible variations of bars shall be as set forth in Table 5.

15.3 Headed bolts shall be semifinished hexagonal in shape, and in accordance with the dimensions for the regular or heavy series, as required, of ANSI B18.2. Unless otherwise specified, the American National Standard heavy hexagon series shall be used.

16. Nuts and Washers

16.1 When specified by the purchaser, the nuts shall be subject to the impact and tension requirements of

this specification. The tests shall be made on test specimens taken from the bar or plate used in the manufacture of the nuts.

17. Threads

17.1 All bolts, stud bolts, and accompanying nuts, unless otherwise specified by the purchaser, shall be threaded in accordance with ANSI B1.1 Class 2A to 2B fit, or British Whitworth threads when specified.

17.2 All threads shall be formed after heat treatment.

18. Inspection

18.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except check analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

18.2 *Certification* — When agreed upon in writing between the manufacturer and the purchaser, a certification that the material conforms to the requirements of this specification shall be the basis of acceptance of the material. Otherwise, the manufacturer shall report to the purchaser or his representative the results of the chemical analysis and mechanical tests made in accordance with this specification. The specification designation included on test reports shall include year of issue and revision letter, if any.

19. Rejection and Rehearing

19.1 *Rejection:*

19.1.1 Unless otherwise specified, any rejection based on tests made in accordance with Sections 9, 10, or 11 shall be reported to the manufacturer within 30 days from the receipt of material by the purchaser.

19.1.2 Material that shows defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

19.2 *Rehearing* — Samples tested in accordance with Sections 9, 10, or 11 that represent rejected material shall be preserved for two months from the date of the test report. In case of dissatisfaction with the results of the test, the manufacturer may make claim for a rehearing within that time.

20. Product Marking

20.1 Grade and manufacturer's identification symbols shall be applied to one end of studs $^{3}/_{8}$ in. [10 mm] in diameter and larger and to the heads of bolts $^{1}/_{4}$ in. [6 mm] in diameter and larger. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) The identification (grade) symbol shall be as shown in Table 2.

20.2 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of the specification.

20.3 *Bar Coding* — In addition to the requirements in 20.1 and 20.2, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard B-5 02.00. If used on small items, the bar code may be applied to the box or a substantially applied tag. **98**

21. Keywords

21.1 marking on fasteners

TABLE 1
TENSILE REQUIREMENTS

Grade	Diameter, in. [mm]	Tensile Strength, min, ksi [MPa]	Yield Strength (0.2% offset) min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Reduction of Area, min, %
B4B	. . .	145 [1000]	105 [720]	13	30
B4C	. . .	115 [790]	85 [585]	18	50
B4D	$2\frac{1}{2}$ [65] and under	125 [860]	105 [720]	18	50
	over $2\frac{1}{2}$ to 4 [65 to 100]	110 [760]	95 [655]	17	45
	over 4 to 7 [100 to 180]	100 [690]	85 [585]	16	45

TABLE 2
CHEMICAL REQUIREMENTS[A]

	Grades B4B, B4C		Grade B4D	
Element	Range, %	Product Variation, %, Over or Under	Range, %	Product Variation, %, Over or Under
Carbon	0.20–0.25	0.02	0.36–0.44	0.02
Manganese	0.50–1.00	0.03	0.45–0.70	0.03
Phosphorus, max	0.025	0.005 over	0.04	0.005 over
Sulfur, max	0.025	0.005 over	0.04	0.005 over
Silicon	0.20–0.50	0.05	0.20–0.35	0.02
Nickel	0.50–1.00	0.03	. . .	. . .
Chromium	11.00–12.50	0.15	0.80–1.15	0.05
Molybdenum	0.90–1.25	0.05	0.50–0.65	0.03
Vanadium	0.20–0.30	0.03	0.25–0.35	0.03
Tungsten	0.90–1.25	0.05	. . .	. . .
Aluminum, max	0.05	. . .	. . .	. . .
Titanium, max	0.05	. . .	. . .	. . .
Tin, max	0.04	. . .	. . .	. . .

[A] Steel to which lead has been added shall not be used.

TABLE 3
IMPACT REQUIREMENTS

Grade	Minimum Impact Value, ft · lbf [J]
B4B	10 [14]
B4C	25 [34]
B4D[A]	25 [34]

[A] For bars over 5 in. [127 mm] diameter only.

TABLE 4
HARDNESS REQUIREMENTS FOR BOLTS AND STUDS

Grade	Brinell Hardness Number, max
B4B	331
B4C	277
B4D	302

TABLE 5
HARDNESS REQUIREMENTS FOR NUTS AND WASHERS

Grade	Brinell Hardness Number	Rockwell Hardness Number
B4B	293–341	C 31–37
B4C	229–277	C 21–29
B4D	263–311	C 27–33

TABLE 6
PERMISSIBLE VARIATIONS IN SIZE OF HOT-ROLLED BARS

Specified Size, in. [mm]	Permissible Variations from Specified Size, in. [mm]		Out of Round, in. [mm]
	Over	Under	
5/16 [8] and under	0.005 [0.13]	0.005 [0.13]	0.008 [0.20]
Over 5/16 to 7/16 [8 to 11], incl	0.006 [0.15]	0.006 [0.15]	0.009 [0.23]
Over 7/16 to 5/8 [11 to 16], incl	0.007 [0.18]	0.007 [0.18]	0.010 [0.25]
Over 5/8 to 7/8 [16 to 22], incl	0.008 [0.20]	0.008 [0.20]	0.012 [0.30]
Over 7/8 to 1 [22 to 25], incl	0.009 [0.23]	0.009 [0.23]	0.013 [0.33]
Over 1 to 1 1/8 [25 to 29], incl	0.010 [0.25]	0.010 [0.25]	0.015 [0.38]
Over 1 1/8 to 1 1/4 [29 to 32], incl	0.011 [0.28]	0.011 [0.28]	0.016 [0.41]
Over 1 1/4 to 1 3/8 [32 to 35], incl	0.012 [0.30]	0.012 [0.30]	0.018 [0.46]
Over 1 3/8 to 1 1/2 [35 to 38], incl	0.014 [0.36]	0.014 [0.36]	0.021 [0.53]
Over 1 1/2 to 2 [38 to 50], incl	1/64 [0.4]	1/64 [0.4]	0.023 [0.58]
Over 2 to 2 1/2 [50 to 65], incl	1/32 [0.8]	0	0.023 [0.58]
Over 2 1/2 to 3 1/2 [65 to 90], incl	3/64 [1.2]	0	0.035 [0.89]
Over 3 1/2 to 4 1/2 [90 to 115], incl	1/16 [1.6]	0	0.046 [1.17]
Over 4 1/2 to 5 1/2 [115 to 140], incl	5/64 [2.0]	0	0.058 [1.47]
Over 5 1/2 to 6 1/2 [140 to 165], incl	1/8 [3.2]	0	0.070 [1.78]
Over 6 1/2 to 7 1/2 [165 to 190], incl	5/32 [4 0]	0	0.085 [2.16]

SUPPLEMENTARY REQUIREMENT

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Marking

S1.1 Grade and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts and studs smaller than $\frac{1}{4}$ in. [6 mm] in diameter and for $\frac{1}{4}$ in. [6 mm] studs requiring more than a total of three symbols, the marking shall be a matter of agreement between the purchaser and manufacturer.

SPECIFICATION FOR QUENCHED AND TEMPERED STEEL BOLTS AND STUDS

SA-449

(Identical to ASTM Specification A 449-92b except for editorial difference in 5.1.4.)

1. Scope

1.1 This specification covers the chemical and mechanical requirements for two types of quenched and tempered steel bolts and studs for general applications where high strength is required.

1.2 The two types of bolts covered in this specification are:

1.2.1 *Type 1* — Medium-carbon steel bolts and studs furnished in nominal diameters of ¼ to 3 in., inclusive.

1.2.2 *Type 2* — Low-carbon martensite or medium-carbon martensite steel bolts and studs furnished in nominal diameters of ¼ to 1 in., inclusive.

1.3 The bolts and studs shall be Type 1; Type 2; or, Type 1 and 2 at manufacturer's option; as specified by the purchaser. When a type is not specified, Type 1 shall be furnished. When elevated temperature applications are involved, Type 1 shall be specified by the purchaser on the order.

1.4 Suitable nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut shall be as follows:

Fastener Size and Surface Finish	Nut Grade and Style[A]
¼ to 1½ in., plain (or with a coating of insufficient thickness to require over-tapped nuts)	B, hex
Over 1½ to 3 in., plain (or with a coating of insufficient thickness to require over-tapped nuts)	A, heavy hex
¼ to 3 in., zinc-coated (or with a coating thickness requiring over-tapped nuts)	DH, heavy hex

[A] Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nut are suitable.

1.5 Unless otherwise specified, washers ordered with bolts shall be furnished to the requirements of Specification F 436.

1.6 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 563 Specification for Carbon and Alloy Steel Nuts
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
D 3951 Practice for Commercial Packaging
F 436 Specification for Hardened Steel Washers
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

2.2 *ANSI/ASME Standards:*

B1.1 Unified Screw Threads
B18.2.1 Square and Hex Bolts and Screws

2.3 *Military Standard:*

MIL-STD-105 Single Sampling Plan for Normal Inspection

3. Ordering Information

3.1 Orders for bolts and studs (including nuts and accessories) under this specification shall include the following:

3.1.1 ASTM designation and year of issue.

3.1.2 Type required, that is, Type 1; Type 2; or Type 1 and 2 at manufacturer's option (see 1.3).

3.1.3 Name of product (that is, bolt or stud).

3.1.4 Quantities (number of pieces by size (including nuts).

3.1.5 Bolt size and length.

3.1.6 *Washers* — Specific quantity and size (separate from bolts).

3.1.7 *Hot Dip or Mechanically Deposited Zinc Coatings* — For hot dip or mechanically deposited zinc coatings covered by 5.1 and requiring overtapped nuts, specify the zinc coating process required, that is, hot dip, mechanically deposited, or no preference (see 5.1).

3.1.8 *Other Coatings* — Specify other protective coating if required (see 5.2).

3.1.9 Specify if inspection at point of manufacture is required.

3.1.10 Specify if certified test reports are required (10.2).

3.1.11 Specify additional testing (see 10.3) or special requirements.

4. Materials and Manufacture

4.1 Steel for bolts and studs shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

4.2 Type 2 bolts and studs shall be made from fully killed fine-grain steel.

4.3 The bolts and studs shall be heat treated by quenching in a liquid medium from above the transformation temperature and then tempering by reheating to a temperature of not less than 800°F (425°C).

4.4 Threads of bolts and studs shall be rolled, cut, or ground.

5. Protective Coatings

5.1 *Zinc, Hot Dip and Mechanically Deposited Requiring Overtapped Nuts:*

5.1.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc-coating process, such as, hot dip, mechanically deposited, or no preference.

5.1.2 When hot dip is specified the fasteners shall be zinc coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153.

5.1.3 When mechanically deposited is specified the fasteners shall be zinc coated by the mechanical-deposition process in accordance with the requirements of Class 50 of Specification B 695.

5.1.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. All components of mating fasteners (that is bolts, nuts, and washers) shall be coated by the same zinc-coating process, and the suppliers option shall be limited to one process per item with no mixed processes in a lot.

5.1.5 Type 2 bolts and studs shall be zinc coated by the mechanical-deposition process only.

NOTE—When the intended application requires that assembled tension exceeds 50% of minimum bolt or stud proof load, an antigalling lubricant may be needed. Application of such a lubricant to nuts and a test of the lubricant efficiency are provided in Supplementary Requirement S1 of Specification A 563 and should be specified when required.

5.2 *Other Coatings:*

5.2.1 Coatings other than specified in 5.1 shall be as specified by the purchaser on the purchase order.

5.2.2 When other coatings are specified, the complete specification for the coating shall be included as part of the purchase order.

6. Chemical Composition

6.1 The bolts and studs shall conform to the chemical composition specified in Table 1 for the type specified.

6.2 Product analyses may be made by the purchaser from finished material representing each lot. The chemical composition thus determined shall conform to the requirements prescribed for product analysis in Table 1.

6.3 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

6.4 Chemical analyses shall be performed in accordance with Test Methods A 751.

7. Mechanical Properties

7.1 Bolts and studs shall not exceed the maximum hardness specified in Table 2.

7.2 Bolts less than three diameter in length and studs less than four diameter in length shall have hardness values not less than the minimum nor more than the maximum limits required by Table 2. This hardness testing is the only mechanical testing requirement for these bolts or studs.

7.3 Bolts and studs other than those excepted in 7.2 shall be subjected to tension tests as specified in 7.4 and 7.5.

7.4 Bolts and studs 1½ in. in diameter or less, other than those excepted in 7.2, shall be tested full size and shall conform to the tensile strength and either the proof load or yield strength requirements specified in Tables 3 and 4.

7.5 Bolts and studs larger than 1½ in. in diameter, other than those excepted in 7.2, shall preferably be tested full size and when so tested, shall conform to the tensile strength and either the proof load or yield strength requirements specified in Tables 3 and 4 respectively. When equipment of sufficient capacity for full-size testing is not available, or when the length of the bolt or stud makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements of Table 5. In the event that bolts are tested by both full size and by the machined test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

7.6 For bolts and studs on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence over low readings of hardness tests.

8. Dimensions

8.1 Unless otherwise specified, the bolts shall be Hex Cap Screw (Finished Hexagon Head) with dimensions conforming to the latest issue of ANSI B18.2.1.

8.2 Studs shall have dimensions conforming to those specified by the purchaser.

8.3 Unless otherwise specified, uncoated threads shall be Coarse Thread Series as specified in the latest issue of ANSI B1.1, and shall have Class 2A tolerances.

8.4 Bolts and studs hot dip or mechanically zinc coated (see 5.1).

8.4.1 Unless otherwise specified, bolts to be used with nuts or tapped holes that have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot-dip or mechanically deposited zinc coating. After zinc coating, the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

Diameter, in.	Oversize Limit, in. (mm)[A]
¼	0.016
5/16, ⅜	0.017
7/16, ½	0.018
9/16 to ¾, incl	0.020
⅞	0.022
1.0 to 1¼, incl	0.024
1⅜, 1½	0.027
1¾ to 3.0, incl	0.050

[A] These values are the same as the overtapping required for zinc-coated nuts in Specification A 563.

8.4.2 The gaging limit for bolts shall be verified during manufacture or use by assembly of a nut tapped as nearly as practical to the amount oversize shown above. In case of dispute, a calibrated thread ring gage of that same size (Class X tolerance, gage tolerance plus) is to be used. Assembly of the gage, or the nut described above, must be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, are to be performed at the frequency and quality described in Table 6.

8.5 *Electroplated Bolts and Studs* — Unless otherwise specified, threads prior to plating shall conform to ANSI/ASME B1.1 Class 2A and after plating shall not exceed the Class 3A maximum limits, that is, Class 2A plus the allowance.

9. Workmanship, Finish, and Appearance

9.1 The bolts and studs shall be commercially smooth and free of burrs, laps, seams, cracks, and other injurious material or manufacturing defects which would make them unsuitable for the intended application.

9.2 Surface discontinuity limits shall be in accordance with Specification F 788/F 788M.

10. Number of Tests and Retests

10.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure

that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

10.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

10.3 When testing on a lot basis is specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all material of one type, that is, bolts or studs having the same nominal diameter and length offered for inspection at one time. From each lot, the number of tests for each specified property shall be as follows:

Number of Pieces in Lot	Number of Samples
800 and less	1
Over 800 to 8 000, incl	2
Over 8 000 to 22 000, incl	3
Over 22 000	5

10.4 Should any sample fail to meet the requirements of a specified test, double the original number of samples from the same lot shall be retested for the requirement(s) in which it failed. All the additional samples shall conform to the specification or the lot shall be rejected.

10.5 If any test specimen shows defective machining, it may be discarded and another specimen substituted.

11. Test Methods

11.1 Tests shall be conducted in accordance with Test Methods F 606.

11.2 The wedge test shall be applicable only to square and hexagon head bolts.

11.3 Studs shall be tested by the Axial Tension Method as described in the second paragraph of Axial Tension Testing of Full-Size Products, Test Methods section of Test Methods F 606.

12. Inspection

12.1 If the inspection described in 12.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

12.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

13. Responsibility

13.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

14. Rejection and Rehearing

14.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

15. Product Marking

15.1 *Manufacturers Identification* — All bolt heads and one end of studs shall be marked with a unique identifier by the manufacturer to identify the manufacturer.

15.2 *Type Identification* — In addition to the requirements in 15.1, all bolt heads and one end of studs $\frac{3}{8}$ in. and larger, and whenever feasible studs less than $\frac{3}{8}$ in., shall be marked to identify the Type as follows:

Type	Marking
1	3 radial lines 120° apart
2	3 radial lines 60° apart

15.3 *Marking Method and Location* — All markings shall be located on the top of the bolt head and may be either raised or depressed, at the option of the manufacturer.

16. Packaging and Package Marking

16.1 *Packaging:*

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When zinc-coated nuts are included on the same order as zinc coated bolts, the bolts and nuts shall be shipped in the same container.

16.1.3 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

16.2 *Package Marking:*

16.2.1 Each shipping unit shall include or be plainly marked with the following information:

16.2.1.1 ASTM designation and type,

16.2.1.2 Size,

16.2.1.3 Name and brand or trademark of the manufacturer,

16.2.1.4 Number of pieces,

16.2.1.5 Purchase order number, and

16.2.1.6 Country of origin.

17. Keywords

17.1 bolts; carbon steel; steel; studs

TABLE 1
CHEMICAL REQUIREMENTS FOR TYPE 1 AND TYPE 2 BOLTS AND STUDS

Element	Composition, %	
	Type 1	Type 2
Carbon:		
Heat analysis	0.28–0.55	0.15–0.38
Product analysis	0.25–0.58	0.13–0.41
Manganese, min:		
Heat analysis	0.60	0.70
Product analysis	0.57	0.67
Phosphorus, max:		
Heat analysis	0.040	0.040
Product analysis	0.048	0.048
Sulfur, max:		
Heat analysis	0.050	0.050
Product analysis	0.058	0.058
Boron, min:		
Heat analysis	. . .	0.0005
Product analysis	. . .	0.0005

TABLE 2
HARDNESS REQUIREMENTS

Bolt or Stud Diameter, in.	Hardness	
	Brinell Hardness Number	Rockwell C
¼ to 1, incl	255 to 321	25 to 34
Over 1 to 1½, incl	223 to 286	19 to 30
Over 1½ to 3, incl	183 to 235	. . .

TABLE 3
TENSILE REQUIREMENTS FOR COARSE-THREAD FULL-SIZE BOLTS AND STUDS

Bolt or Stud Diameter, in.	Threads per inch[A]	Stress Area,[B] in.^{2}	Tensile Load, min, lbf[C]	Proof Load, Length Measurement Method, lbf[C]	Alternative Proof Load, Yield Strength Method (0.2% Offset), lbf[C]
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
1/4	20	0.0318	3 800	2 700	2 900
5/16	18	0.0524	6 300	4 450	4 800
3/8	16	0.0775	9 300	6 600	7 100
7/16	14	0.1063	12 750	9 050	9 800
1/2	13	0.1419	17 050	12 050	13 050
9/16	12	0.182	21 850	15 450	16 750
5/8	11	0.226	27 100	19 200	20 800
3/4	10	0.334	40 100	28 400	30 700
7/8	9	0.462	55 450	39 250	42 500
1	8	0.606	72 700	51 500	55 750
1 1/8	7	0.763	80 100	56 450	61 800
1 1/4	7	0.969	101 700	71 700	78 500
1 3/8	6	1.155	121 300	85 450	93 550
1 1/2	6	1.405	147 500	104 000	113 800
1 3/4	5	1.90	171 000	104 500	110 200
2	4 1/2	2.50	225 000	137 500	145 000
2 1/4	4 1/2	3.25	292 500	178 750	188 500
2 1/2	4	4.00	360 000	220 000	232 000
2 3/4	4	4.93	443 700	271 150	286 000
3	4	5.97	537 300	328 350	346 200

[A] For 8 threads per inch sizes 1 1/8 to 1 1/2 in., inclusive, stresses of 105 000 psi (725 MPa), 74 000 psi (510 MPa), and 81 000 psi (560 MPa) shall be used for calculating the values in columns 4, 5, and 6 respectively.

[B] Stress area is calculated as follows:

$$A_s = 0.7854\,[D - (0.9743/n)]^2$$

where:
A_s = stress area,
D = nominal diameter, and
n = threads per inch.

[C] Values tabulated are based on the following:

Bolt Size, in.	Column 4, psi (MPa)	Column 5, psi (MPa)	Column 6, psi (MPa)
1/4 to 1, incl	120 000 (825)	85 000 (585)	92 000 (635)
1 1/8 to 1 1/2, incl	105 000 (725)	74 000 (510)	81 000 (560)
1 3/4 to 3, incl	90 000 (620)	55 000 (380)	58 000 (400)

TABLE 4
TENSILE REQUIREMENTS FOR FINE-THREAD FULL-SIZE BOLTS AND STUDS

Bolt or Stud Diameter, in.	Threads per inch	Stress Area,[A] in.[2]	Tensile Load, min, lbf[B]	Proof Load, Length Measurement Method, lbf[B]	Alternative Proof Load, Yield Strength Method (0.2% Offset), min, lbf[B]
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
1/4	28	0.0364	4 350	3 100	3 500
5/16	24	0.0580	6 950	4 950	5 350
3/8	24	0.0878	10 550	7 450	8 100
7/16	20	0.1187	14 500	10 100	10 900
1/2	20	0.1599	19 200	13 600	14 700
9/16	18	0.203	24 350	17 250	18 700
5/8	18	0.256	30 700	21 750	23 500
3/4	16	0.373	44 750	31 700	34 300
7/8	14	0.509	61 100	43 250	46 800
1	12	0.663	79 550	56 350	61 000
1 1/8	12	0.856	89 900	63 350	69 350
1 1/4	12	1.073	112 650	79 400	86 900
1 3/8	12	1.315	138 100	97 300	106 500
1 1/2	12	1.581	166 000	117 000	128 000

[A] See footnote *B* in Table 3.
[B] See footnote *C* in Table 3.

TABLE 5
TENSILE REQUIREMENTS FOR SPECIMENS MACHINED FROM BOLTS AND STUDS

Bolt or Stud Diameter, in.	Tensile Strength, min, psi (MPa)	Yield Strength, min, psi (MPa)	Elongation in 4 *D*, min, %	Reduction of Area, min, %
1/4 to 1, incl	120 000 (825)	92 000 (635)	14	35
Over 1 to 1 1/2, incl	105 000 (725)	81 000 (560)	14	35
Over 1 1/2 to 3, incl	90 000 (620)	58 000 (400)	14	35

TABLE 6
SAMPLE SIZES AND ACCEPTANCE NUMBERS FOR INSPECTION OF HOT-DIP OR MECHANICALLY DEPOSITED ZINC-COATED THREADS

Lot Size	Sample Size[A,B]	Acceptance Number[A]
2 to 90	13	1
91 to 150	20	2
151 to 280	32	3
281 to 500	50	5
501 to 1 200	80	7
1 201 to 3 200	125	10
3 201 to 10 000	200	14
10 001 and over	315	21

[A] Sample sizes of acceptance numbers are extracted from "Single Sampling Plan for Normal Inspection," Table IIA, MIL-STD-105.
[B] Inspect all bolts in the lot if the lot size is less than the sample size.

SUPPLEMENTARY REQUIREMENT

S1. Marking

S1.1 Studs that are continuously threaded with the same class of thread shall be marked on each end with the marking required by Section 15.

S1.2 Marking small sizes (customarily less than 0.375 in. [9.525 mm]) may not be practical. Consult the producer for the minimum size that can be marked.

SPECIFICATION FOR GENERAL REQUIREMENTS FOR CARBON, FERRITIC ALLOY, AND AUSTENITIC ALLOY STEEL TUBES

SA-450/SA-450M

(Identical with ASTM Specification A 450/A 450M-96.) 98

1. Scope

1.1 This specification covers a group of requirements which, with the exceptions of 4.3 and Sections 5, 6, 17, 18, 19, 20, 21, 22, and 23, are mandatory requirements to the following ASTM tubular product specifications:

Title of Specification	ASTM Designation[A]
Seamless Low-Carbon and Carbon-Molybdenum Steel Still Tubes for Refinery Service	A 161
Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler Tubes	A 178/A 178M
Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes	A 179/A 179M
Seamless Carbon Steel Boiler Tubes for High-Pressure Service	A 192/A 192M
Seamless Cold-Drawn Intermediate Alloy-Steel Heat-Exchanger and Condenser Tubes	A 199/A 199M
Seamless Intermediate Alloy-Steel Still Tubes for Refinery Service	A 200
Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes	A 209/A 209M
Seamless Medium-Carbon Steel Boiler and Superheater Tubes	A 210/A 210M
Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes	A 213/A 213M
Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes	A 214/A 214M
Electric-Resistance-Welded Carbon Steel Boiler and Superheater Tubes for High-Pressure Service	A 226/A 226M
Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes	A 249/A 249M
Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes	A 250/A 250M
Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service	A 268/A 268M
Seamless and Welded Austenitic Stainless Steel Tubing for General Service	A 269
Seamless and Welded Austenitic Stainless Steel Sanitary Tubing	A 270
Seamless Austenitic Chromium-Nickel Steel Still Tubes for Refinery Service	A 271
Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service	A 334/A 334M
Seamless and Electric-Welded Low-Alloy Steel Tubes	A 423/A 423M
Electric-Resistance-Welded Coiled Steel Tubing for Gas and Fuel Oil Lines	A 539
Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes	A 556/A 556M
Electric-Resistance-Welded Carbon Steel Feedwater Heater Tubes	A 557/A 557M
Welded Austenitic Stainless Steel Feedwater Heater Tubes	A 688/A 688M
Seamless Medium-Strength Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes	A 692
Austenitic Stainless Steel Tubing for Breeder Reactor Core Components	A 771
Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service	A 789/A 789M
Welded Unannealed Ferritic Stainless Steel Tubing	A 791/A 791M
Welded Ferritic Stainless Steel Feedwater Heater Tubes	A 803/A 803M
Seamless, Cold-Drawn Carbon Steel Tubing for Hydraulic System Service	A 822

Title of Specification	ASTM Designation[A]
Austenitic and Ferritic Stainless Steel Duct Tubes for Breeder Reactor Core Components	A 826
High-Frequency Induction-Welded, Unannealed Austenitic Steel Condenser Tubes	A 851

[A] These designations refer to the latest issue of the respective specifications.

1.2 One or more of Sections 4.3, 5, 6, 17, 18, 19, 20, 21, 22, and 23 apply when the product specification or purchase order has a requirement for the test or analysis described by these sections.

1.3 In case of conflict between a requirement of the product specification and a requirement of this general requirement specification only the requirement of the product specification need be satisfied.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation (SI) of the product specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

D 3951 Practice for Commercial Packaging

E 92 Test Method for Vickers Hardness of Metallic Materials

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E 426 Practice for Electromagnetic (Eddy-Current) Testing of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *Federal Standard:*

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.3 *Military Standards:*

MIL-STD-271 Nondestructive Testing Requirements for Metals

MIL-STD-792 Identification Marking Requirements for Special Purpose Equipment

2.4 *Steel Structures Painting Council:*

SSPC-SP6 Surface Preparation Specification No. 6 Commercial Blast Cleaning

2.5 *Other Document:*

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification

3. Process

3.1 The steel may be made by any process.

3.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

3.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, such as electroslag remelting or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

3.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

4. Chemical Composition

4.1 Samples for chemical analysis, and method of analysis, shall be in accordance with Test Methods, Practices, and Terminology A 751.

4.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufac-

turer, shall conform to the requirements specified in the product specification.

4.2.1 For stainless steels ordered under product specifications referencing this specification of general requirements, the steel shall not contain an unspecified element, other than nitrogen, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation in a table of chemical requirements within any specification listed within the scope as being covered by this specification.

4.3 *Product Analysis*—Product analysis requirements and options, if any, are contained in the product specification.

5. Tensile Properties

5.1 The material shall conform to the requirements as to tensile properties prescribed in the individual specification.

5.2 The yield strength corresponding to a permanent offset of 0.2% of the gage length or to a total extension of 0.5% of the gage length under load shall be determined.

5.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. [19.0 mm] from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

6. Standard Weights

6.1 The calculated weight per foot, based upon a specified minimum wall thickness, shall be determined by the following equation:

$$W = C(D - t)t \quad (1)$$

where:

C = 10.69 [0.02466/15],
W = weight, lb/ft [kg/m],
D = specified outside diameter, in. [mm], and
t = specified minimum wall thickness, in. [mm].

6.2 The permissible variations from the calculated weight per foot [kilogram per metre] shall be as prescribed in Table 1.

7. Permissible Variations in Wall Thickness

7.1 Variations from the specified minimum wall thickness shall not exceed the amounts prescribed in Table 2.

7.2 For tubes 2 in. [50.8 mm] and over in outside diameter and 0.220 in. [5.6 mm] and over in thickness, the variation in wall thickness in any one cross section of any one tube shall not exceed the following percentage of the actual mean wall at the section. The actual mean wall is defined as the average of the thickest and thinnest wall in that section.

Seamless tubes ±10%
Welded tubes ±5%

7.3 When cold-finished tubes as ordered require wall thicknesses $\frac{3}{4}$ in. [19.1 mm] or over, or an inside diameter 60% or less of the outside diameter, the permissible variations in wall thickness for hot-finished tubes shall apply.

8. Permissible Variations in Outside Diameter

8.1 Except as provided in 8.2.1 and 8.3, variations from the specified outside diameter shall not exceed the amounts prescribed in Table 3.

8.2 Thin-wall tubes usually develop significant ovality (out of roundness) during final annealing, or straightening, or both. Thin-wall tubes are defined as those meeting the specified outside diameters and specified wall thicknesses set forth as follows:

Specified Outside Diameter	Specified Wall Thickness
2 in. [50.8 mm] and less	2% or less of specified outside diameter
Greater than 2 in. [50.8 mm]	3% or less of specified outside diameter
All diameters	0.020 in. [0.5 mm] or less

8.2.1 The diameter tolerances of Table 3 are not sufficient to provide for additional ovality expected in thin-wall tubes, and, for such tubes, are applicable only to the *mean* of the extreme (maximum and minimum) outside diameter readings in any one cross section. However, for thin wall tubes the *difference* in extreme outside diameter readings (ovality) in any one cross section shall not exceed the following ovality allowances:

Outside Diameter	Ovality Allowance
1 in. [25.4 mm] and under	0.020 in. [0.5 mm]
Over 1 in. [25.4 mm]	2.0% of specified outside diameter

8.3 For cold-finished seamless austenitic and ferritic/austenitic tubes an ovality allowance is necessary for all sizes less than 2 in. [50.8 mm] outside diameter since they are likely to become out of round during their final heat treatment. In such tubes, the maximum and minimum diameters at any cross section shall deviate from the nominal diameter by no more than ±0.010 in. [±0.25 mm]; however, the mean diameter at that cross section must still be within the given permissible variation given in Table 3. In the event of conflict between the provisions of 8.3 and those of 8.2.1, the larger value of ovality tolerance shall apply.

9. Permissible Variations in Length

9.1 Variations from the specified length shall not exceed the amounts prescribed in Table 4.

10. Permissible Variations in Height of Flash on Electric-Resistance-Welded Tubes

10.1 For tubes over 2 in. [50.8 mm] in outside diameter, or over 0.135 in. [3.44 mm] in wall thickness, the flash on the inside of the tubes shall be mechanically removed by cutting to a maximum height of 0.010 in. [0.25 mm] at any point on the tube.

10.2 For tubes 2 in. [50.8 mm] and under in outside diameter and 0.135 in. [3.4 mm] and under in wall thickness, the flash on the inside of the tube shall be mechanically removed by cutting to a maximum height of 0.006 in. [0.15 mm] at any point on the tube.

11. Straightness and Finish

11.1 Finished tubes shall be reasonably straight and have smooth ends free of burrs. They shall have a workmanlike finish. Surface imperfections (Note 1) may be removed by grinding, provided that a smooth curved surface is maintained, and the wall thickness is not decreased to less than that permitted by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

NOTE 1—An imperfection is any discontinuity or irregularity found in the tube.

12. Repair by Welding

12.1 Repair welding of base metal defects in tubing is permissible only with the approval of the purchaser and with the further understanding that the tube shall be marked "WR" and the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable specification. Each length of repaired tube shall be tested hydrostatically as required by the product specification.

12.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

13. Retests

13.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional tubes of double the original number from the same group or lot, each of which shall conform to the requirements specified.

14. Retreatment

14.1 If the individual tubes or the tubes selected to represent any group or lot fail to conform to the test requirements, the individual tubes or the group or lot represented may be retreated and resubmitted for test. Not more than two reheat treatments shall be permitted.

15. Test Specimens

15.1 Test specimens shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free of burrs and flaws.

15.2 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

16. Method of Mechanical Testing

16.1 The specimens and mechanical tests required shall be made in accordance with Annex A2 of Test Methods and Definitions A 370.

16.2 Specimens shall be tested at room temperature.

16.3 Small or subsize specimens as described in Test Methods and Definitions A 370 may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

17. Flattening Test

17.1 A section of tube not less than $2\frac{1}{2}$ in. [63 mm] in length for seamless and not less than 4 in. [100 mm] in length for welded shall be flattened cold between parallel plates in two steps. For welded tubes, the weld shall be placed 90° from the direction of the applied force (at a point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks, except as provided for in 17.4, on the inside, outside, or end surfaces shall occur in seamless tubes, or on the inside or outside surfaces of welded tubes, until the distance between the plates is less than the value of H calculated by the following equation:

$$H = \frac{(1 + e)t}{e + t/D} \quad (2)$$

where:

H = distance between flattening plates, in. [mm],
t = specified wall thickness of the tube, in. [mm],
D = specified outside diameter of the tube, in. [mm], and
e = deformation per unit length (constant for a given grade of steel: 0.07 for medium-carbon steel (maximum specified carbon 0.19% or greater), 0.08 for ferritic alloy steel, 0.09 for austenitic steel, and 0.09 for low-carbon steel (maximum specified carbon 0.18% or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the tube meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

17.2 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

17.3 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

17.4 When low D-to-t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D to t ratio is less than 10.

18. Reverse Flattening Test

18.1 A section 4 in. [100 mm] in length of finished welded tubing in sizes down to and including $\frac{1}{2}$ in. [12.7 mm] in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

19. Flaring Test

19.1 A section of tube approximately 4 in. [100 mm] in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded to the percentages specified in Table 5 without cracking or showing imperfections rejectable under the provisions of the product specification.

20. Flange Test

20.1 A section of tube shall be capable of having a flange turned over at a right angle to the body of the tube without cracking or showing imperfections rejectable under the provisions of the product specification. The width of the flange for carbon and alloy steels shall be not less than the percentages specified in Table 6. For the austenitic grades, the width of the flange for all sizes listed in Table 6 shall be not less than 15%.

21. Hardness Test

21.1 For tubes 0.200 in. [5.1 mm] and over in wall thickness, either the Brinell or Rockwell hardness test shall be used. When Brinell hardness testing is used, a 10 mm ball with 3000, 1500, or 500 kg load, or a

5 mm ball with 750 kg load may be used, at the option of the manufacturer.

21.2 For tubes less than 0.200 in. [5.1 mm] to and including 0.065 in. [1.7 mm] in wall thickness, the Rockwell hardness test shall be used.

21.3 For tubes less than 0.065 in. [1.7 mm] in wall thickness, the hardness test shall not be required.

21.4 The Brinell hardness test may be made on the outside of the tube near the end, on the outside of a specimen cut from the tube, or on the wall cross section of a specimen cut from the tube at the option of the manufacturer. This test shall be made so that the distance from the center of the impression to the edge of the specimen is at least 2.5 times the diameter of the impression.

21.5 The Rockwell hardness test may be made on the inside surface, on the wall cross section, or on a flat on the outside surface at the option of the manufacturer.

21.6 For tubes furnished with upset, swaged, or otherwise formed ends, the hardness test shall be made as prescribed in 21.1 and 21.2 on the outside of the tube near the end after the forming operation and heat treatment.

21.7 For welded or brazed tubes, the hardness test shall be made away from the joints.

21.8 When the product specification provides for Vickers hardness, such testing shall be in accordance with Test Method E 92.

22. Hydrostatic Test

22.1 Except as provided in 22.2 and 22.3, each tube shall be tested by the manufacturer to a minimum hydrostatic test pressure determined by the following equation:

$$\textit{Inch-Pound Units: } P = 32000\ t/D \qquad (3)$$

$$\textit{SI Units: } P = 220.6\ t/D$$

where:

P = hydrostatic test pressure, psi or MPa,
t = specified wall thickness, in. or mm, and
D = specified outside diameter, in. or mm.

22.1.1 The hydrostatic test pressure determined by Eq. (3) shall be rounded to the nearest 50 psi [0.5 MPa] for pressure below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending, or other forming operations, or both.

22.2 Regardless of the determination made by Eq. (3), the minimum hydrostatic test pressure required to satisfy these requirements need not exceed the values given in Table 7. This does not prohibit testing at higher pressures at manufacturer's option or as provided in 22.3.

22.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 22.2 or 22.1, or both, may be stated on the order. The tube wall stress shall be determined by the following equation:

$$S = PD/2t \qquad (4)$$

where:

S = tube wall stress, psi or MPa, and all other symbols as defined in 22.1.

22.4 The test pressure shall be held for a minimum of 5 s.

22.5 If any tube shows leaks during the hydrostatic test, it shall be rejected.

22.6 The hydrostatic test may not be capable of testing the end portion of the pipe. The lengths of pipe that cannot be tested shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

23. Air Underwater Pressure Test

23.1 When this test is employed, each tube, with internal surface clean and dry, shall be internally pressurized to 150 psi [1000 kPa] minimum with clean and dry compressed air while being submerged in clear water. The tube shall be well-lighted, preferably by underwater illumination. Any evidence of air leakage of the pneumatic couplings shall be corrected prior to testing. Inspection shall be made of the entire external surface of the tube after holding the pressure for not less than 5 s after the surface of the water has become calm. If any tube shows leakage during the air underwater test, it shall be rejected. Any leaking areas may be cut out and the tube retested.

24. Nondestructive Electric Test

24.1 When nondestructive examination is specified by the purchaser or the product specification, each tube shall be examined by a nondestructive examination method in accordance with Practice E 213, Practice E 309 (for ferromagnetic materials), Practice E 426 (for non-magnetic materials), or Practice E 570. Upon agreement, Practice E 273 shall be employed in addition to one of the full periphery tests. The range of tube sizes that may be examined by each method shall be subject to the limitations in the scope of that practice. In case of conflict between these methods and practices and this specification, the requirements of this specification shall prevail.

24.2 The following information is for the benefit of the user of this specification:

24.2.1 Calibration standards for the nondestructive electric test are convenient standards for calibration of nondestructive testing equipment only. For several reasons, including shape, orientation, width, etc., the correlation between the signal produced in the electric test from an imperfection and from calibration standards is only approximate. A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

24.2.2 The ultrasonic examination referred to in this specification is intended to detect longitudinal discontinuities having a reflective area similar to or larger than the calibration reference notches specified in 23.4. The examination may not detect circumferentially oriented imperfections or short, deep defects.

24.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type. Practices E 309 and E 426 contain additional information regarding the capabilities and limitations of eddy-current examination.

24.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. The provisions of this specification only provide for longitudinal calibration for flux leakage. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

24.2.5 The hydrostatic test referred to in Section 22 is a test method provided for in many product specifications. This test has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall defects or defects that extend an appreciable distance into the wall without complete penetration.

24.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular products.

24.3 *Time of Examination* — Nondestructive examination for specification acceptance shall be performed after all deformation processing, heat treating, welding, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

24.4 *Surface Condition:*

24.4.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

24.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

24.5 *Extent of Examination:*

24.5.1 The relative motion of the tube and the transducer(s), coil(s), or sensor(s) shall be such that the entire tube surface is scanned, except for end effects as noted in 24.5.2.

24.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

24.6 *Operator Qualifications:*

24.6.1 The test unit operator shall be certified in accordance with SNT TC-1-A, or an equivalent documented standard agreeable to both purchaser and manufacturer.

24.7 *Test Conditions:*

24.7.1 For examination by the ultrasonic method, the minimum nominal transducer frequency shall be

2.0 MHz, and the maximum transducer size shall be 1.5 in. (38 mm).

24.7.2 For eddy current testing, the excitation coil frequency shall be chosen to ensure adequate penetration, yet provide good signal-to-noise ratio.

24.7.2.1 The maximum coil frequency shall be:

Specified Wall Thickness	Maximum Frequency
<0.050 in.	100 KHz
0.050 to 0.150	50
>0.150	10

24.8 *References Standards:*

24.8.1 Reference standards of convenient length shall be prepared from a length of tube of the same grade, specified size (outside diameter and wall thickness), surface finish and heat treatment condition as the tubing to be examined.

24.8.2 *For eddy current testing,* the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

24.8.2.1 *Drilled Hole* — The reference standard shall contain three or more holes, equally spaced circumferentially around the tube and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the tube wall, with care being taken to avoid distortion of the tube while drilling. The holes shall not be larger than 0.031 in. (0.8 mm) in diameter. As an alternative, the producer may choose to drill one hole and run the calibration standard through the test coil three times, rotating the tube approximately 120° each time. More passes with smaller angular increments may be used, provided testing of the full 360° of the coil is obtained. For welded tubing, if the weld is visible, one of the multiple holes or the single hole shall be drilled in the weld.

24.8.2.2 *Transverse Tangential Notch* — Using a round tool or file with a $\frac{1}{4}$ in. [6.4 mm] diameter, a notch shall be milled or filed tangential to the surface and transverse to the longitudinal axis of the tube. Said notch shall have a depth not exceeding $12\frac{1}{2}$% of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater.

24.8.2.3 *Longitudinal Notch* — A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding $12\frac{1}{2}$% of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

24.8.3 *For ultrasonic testing,* the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of notches shall not exceed $12\frac{1}{2}$% of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The width of the notch shall not exceed two times the depth. For welded tubing, the notch shall be placed in the weld, if the weld is visible.

24.8.4 *For flux leakage testing,* the longitudinal reference notches shall be straight-sided notches machined in a radial plane parallel to the tube axis on the inside and outside surfaces of the tube. Notch depth shall not exceed $12\frac{1}{2}$% of the specified wall thickness, or 0.004 in. [0.1 mm], whichever is greater. Notch length shall not exceed 1 in. [25 mm], and the width shall not exceed the depth. Outside diameter and inside diameter notches shall have sufficient separation to allow distinct identification of the signal from each notch.

24.8.5 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

24.9 *Standardization Procedure:*

24.9.1 The test apparatus shall be standardized at the beginning and end of each series of tubes of the same specified size (diameter and wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h during the examination of such tubing. More frequent standardizations may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

24.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss or shutdown.

24.9.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the tube to be tested, except that, at the manufacturer's discretion, the tubes may be tested at a higher sensitivity.

24.9.4 The signal-to-noise ratio for the reference standard shall be 2.5:1 or greater, and the reference signal amplitude for each discontinuity shall be at least 50% of full scale of the display. In establishing the noise level, extraneous signals from identifiable surface

imperfections on the reference standard may be ignored. When reject filtering is used during UT testing, linearity must be demonstrated.

24.9.5 If, upon any standardization, the reference signal amplitude has decreased by 29% (3.0 dB), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s), or sensor(s) adjusted, and the unit restandardized, but all tubes tested since the last acceptable standardization must be retested.

24.10 *Evaluation of Imperfections:*

24.10.1 Tubing producing a test signal to or greater than the lowest signal produced by the reference standard shall be designated suspect, shall be clearly marked or identified, and shall be separated from the acceptable tubing.

24.10.2 Such suspect tubing shall be subject to one of the following three dispositions:

24.10.2.1 The tubes may be rejected without further examination, at the discretion of the manufacturer.

24.10.2.2 If the test signal was produced by imperfections such as scratches, surface roughness, dings, straightener marks, loose ID bead and cutting chips, steel die stamps, stop marks, tube reducer ripple, or chattered flash trim, the tubing may be accepted or rejected depending on visual observation of the severity of the imperfection, the type of signal it produces on the testing equipment used, or both.

24.10.2.3 If the test signal was produced by imperfections which cannot be identified, or was produced by cracks or crack-like imperfections, the tubing shall be rejected.

24.10.3 Any tubes with imperfections of the types in 24.10.2.2 and 24.10.2.3, exceeding 0.004 in. (0.1 mm) or 12½% of the specified minimum wall thickness (whichever is greater) in depth shall be rejected.

24.10.4 Rejected tubes may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. If grinding is performed, the outside diameter in the area of grinding may be reduced by the amount so removed. To be accepted, reconditioned tubes must pass the nondestructive examination by which they were originally rejected.

25. Inspection

25.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

26. Rejection

26.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

26.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

27. Certified Test Report

27.1 When specified in the purchase order or contract, the producer or supplier shall furnish a Certified Test Report certifying that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirements designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the Certified Test Report, but the document shall be dated and shall clearly identify the organization submitting the Report.

NOTE 2—Notwithstanding the absence of a signature or notarization, the organization submitting the Report is responsible for the contents of the Report.

27.2 In addition, the Certified Test Report shall include the following information and test results, when applicable:

27.2.1 Heat Number,

27.2.2 Heat Analysis,

27.2.3 Product Analysis, when specified,

27.2.4 Tensile Properties,

27.2.5 Width of the gage length, when longitudinal strip tension test specimens are used,

27.2.6 Flattening Test acceptable,

27.2.7 Reverse Flattening Test acceptable,

27.2.8 Flaring Test acceptable,

27.2.9 Flange Test acceptable,

27.2.10 Hardness Test values,

27.2.11 Hydrostatic Test pressure,

27.2.12 Non-destructive Electric Test method,

27.2.13 Impact Test results, and

27.2.14 Other test results or information required to be reported by the product specification.

27.3 Test results or information required to be reported by supplementary requirements, or other requirements designated in the purchase order or contract shall be reported, but may be reported in a separate document.

27.4 The Certified Test Report shall include a statement of explanation for the letter added to the specification number marked on the tubes (see 28.3), when all of the requirements of the specification have not been completed. The purchaser must certify that all requirements of the specification have been completed before removal of the letter (that is, X, Y, or Z).

28. Product Marking

28.1 Each length of tube shall be legibly stenciled with the manufacturer's name or brand, the specification number, and grade. The marking need not include the year date of the specification. For tubes less than $1\frac{1}{4}$ in. [31.8 mm] in diameter and tubes under 3 ft [1 m] in length, the required information may be marked on a tag securely attached to the bundle or box in which the tubes are shipped.

28.2 For austenitic tubes, the marking paint or ink shall not contain any harmful metal, or metal salts, such as zinc, lead, or copper, which cause corrosive attack on heating.

28.3 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicate that all requirements of the specification have not been completed by a letter such as X, Y, or Z, immediately following the specification number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in Section 27.

28.4 *Bar Coding* — In addition to the requirements in 28.1, 28.2, and 28.3, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

29. Packaging, Marking, and Loading

29.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with the procedures of Practices A 700.

30. Government Procurement

30.1 *Scale Free Pipe:*

30.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale free tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

30.1.2 Tube shall be ordered to outside diameter (OD) and wall thickness.

30.1.3 *Responsibility for Inspection* — Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however,

this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept the material. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

30.1.4 *Sampling for Flattening and Flaring Tests and for Visual and Dimensional Examination* — Minimum sampling for flattening and flaring tests and visual and dimensional examination shall be as follows:

Lot Size (pieces per lot)	Sample Size
2 to 8	Entire lot
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 10 000	38
10 001 to 35 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots may be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance.

30.1.5 *Sampling for Chemical Analysis* — One sample for chemical analysis shall be selected from each of two tubes chosen from each lot. A lot shall be all material poured from one heat.

30.1.6 *Sampling for Tension and Bend Test* — One sample shall be taken from each lot. A lot shall consist of all tube of the same outside diameter and wall thickness manufactured during an 8-h shift from the same heat of steel, and heat treated under the same conditions of temperature and time in a single charge in a batch type furnace, or heat treated under the same condition in a continuous furnace, and presented for inspection at the same time.

30.1.7 *Hydrostatic and Ultrasonic Tests* — Each tube shall be tested by the ultrasonic (when specified) and hydrostatic tests.

30.1.8 Tube shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel tube shall be pickled or blast cleaned to a free of scale condition equivalent to the CSa2 visual standard listed in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

30.1.9 In addition to the marking in Specification A 530/A 530M, each length of tube ¼ in. outside diameter and larger shall be marked with the following listed information. Marking shall be in accordance with FED-STD-183 and MIL-STD-792. *(a)* Outside diameter, wall thickness, and length *(b)* Heat or lot identification number.

30.1.10 Tube shall be straight to within the tolerances specified in Table 8.

30.1.11 When specified, each tube shall be ultrasonically examined in accordance with MIL-STD-271, except that the notch depth in the calibration standard shall be 5% of the wall thickness or 0.005 in., whichever is greater. Any tube which produces an indication equal to or greater than 100% of the indication from the calibration standard shall be rejected.

30.1.12 The tube shall be free from repair welds, welded joints, laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the tube as determined by visual and ultrasonic examination, or alternate tests, as specified.

30.1.13 Tube shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality tubing. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered injurious if the imperfections are removable within the tolerances specified for wall thickness or 0.005 in., whichever is greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.

30.1.14 No weld repair by the manufacturer is permitted.

30.1.15 Preservation shall be level A or commercial, and packing shall be level A, B, or commercial, as specified. Level A preservation and level A or B packing shall be in accordance with MIL-STD-163

and commercial preservation and packing shall be in accordance with Practices A 700 or Practice D 3951.

31. Keywords

31.1 alloy steel tube; austenitic stainless steel; carbon steel tube; general delivery; stainless steel tube; steel tube

TABLE 1
PERMISSIBLE VARIATIONS IN WEIGHT PER FOOT[A]

Method of Manufacture	Permissible Variation in Weight per Foot, % Over	Under
Seamless, hot-finished	16	0
Seamless, cold-finished:		
1½ in. [38.1 mm] and under OD	12	0
Over 1½ in. [38.1 mm] OD	13	0
Welded	10	0

[A] These permissible variations in weight apply to lots of 50 tubes or more in sizes 4 in. [101.6 mm] and under in outside diameter, and to lots of 20 tubes or more in sizes over 4 in. [101.6 mm] in outside diameter.

TABLE 2
PERMISSIBLE VARIATIONS IN WALL THICKNESS[A]

Outside Diameter, in. [mm]	Wall Thickness, %							
	0.095 [2.4] and Under		Over 0.095 to 0.150 [2.4 to 3.8], incl		Over 0.150 to 0.180 [3.8 to 4.6], incl		Over 0.180, [4.6]	
	Over	Under	Over	Under	Over	Under	Over	Under
Seamless, Hot-Finished Tubes								
4 [101.6] and under	40	0	35	0	33	0	28	0
Over 4 [101.6]	. . .	. . .	35	0	33	0	28	0

	Over	Under
Seamless, Cold-Finished Tubes		
1½ [38.1] and under	20	0
Over 1½ [38.1]	22	0
Welded Tubes		
All sizes	18	0

[A] These permissible variations in wall thickness apply only to tubes, except internal-upset tubes, as rolled or cold-finished, and before swaging, expanding, bending, polishing, or other fabricating operations.

TABLE 3
PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETER[A]

Outside Diameter, in. [mm]	Permissible Variations, in. [mm] Over	Under
Hot-Finished Seamless Tubes		
4 [101.6] and under	1/64 [0.4]	1/32 [0.8]
Over 4 to 7½ [101.6 to 190.5], incl	1/64 [0.4]	3/64 [1.2]
Over 7½ to 9 [190.5 to 228.6], incl	1/64 [0.4]	1/16 [1.6]
Welded Tubes and Cold-Finished Seamless Tubes		
Under 1 [25.4]	0.004 [0.1]	0.004 [0.1]
1 to 1½ [25.4 to 38.1], incl	0.006 [0.15]	0.006 [0.15]
Over 1½ to 2 [38.1 to 50.8], excl	0.008 [0.2]	0.008 [0.2]
2 to 2½ [50.8 to 63.5], excl	0.010 [0.25]	0.010 [0.25]
2½ to 3 [63.5 to 76.2], excl	0.012 [0.3]	0.012 [0.3]
3 to 4 [76.2 to 101.6], incl	0.015 [0.38]	0.015 [0.38]
Over 4 to 7½ [101.6 to 190.5], incl	0.015 [0.38]	0.025 [0.64]
Over 7½ to 9 [190.5 to 228.6], incl	0.015 [0.38]	0.045 [1.14]

[A] Except as provided in 8.2 and 8.3, these permissible variations include out-of-roundness. These permissible variations in outside diameter apply to hot-finished seamless, welded and cold-finished seamless tubes before other fabricating operations such as upsetting, swaging, expanding, bending, or polishing.

98

TABLE 4
PERMISSIBLE VARIATIONS IN LENGTH[A]

Method of Manufacture	Outside Diameter, in. [mm]	Cut Length, in. [mm] Over	Under
Seamless, hot-finished	All sizes	3/16 [5]	0 [0]
Seamless, cold-finished	Under 2 [50.8]	1/8 [3]	0 [0]
	2 [50.8] and over	3/16 [5]	0 [0]
Welded	Under 2 [50.8]	1/8 [3]	0 [0]
	2 [50.8] and over	3/16 [5]	0 [0]

[A] These permissible variations in length apply to tubes before bending. They apply to cut lengths up to and including 24 ft [7.3 m]. For lengths over 24 ft [7.3 m], the above over-tolerances, of 1/8 in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft or ½ in. [13 mm], whichever is lesser.

TABLE 5
FLARING TEST REQUIREMENTS

Ratio of Inside Diameter to Outside Diameter[4]	Minimum Expansion of Inside Diameter, %	
	Carbon, Carbon-Molybdenum, and Austenitic Steels	Other Ferritic Alloy Steels
0.9	21	15
0.8	22	17
0.7	25	19
0.6	30	23
0.5	39	28
0.4	51	38
0.3	68	50

[4] In determining the ratio of inside diameter to specified outside diameter, the inside diameter shall be defined as the actual mean inside diameter of the material tested.

TABLE 6
FLANGE REQUIREMENTS

Outside Diameter of Tube, in. [mm]	Width of Flange
To 2½ [63.5], incl	15% of OD
Over 2½ to 3¾ [63.5 to 95.2], incl	12½% of OD
Over 3¾ to 8 [95.2 to 203.2], incl	10% of OD

TABLE 7
HYDROSTATIC TEST PRESSURES

Outside Diameter of Tube, in. [mm]	Hydrostatic Test Pressure, psi [MPa]
Under 1 [25.4]	1000 [7]
1 to 1½ [25.4 to 38.1], excl	1500 [10]
1½ to 2 [38.1 to 50.8], excl	2000 [14]
2 to 3 [50.8 to 76.2], excl	2500 [17]
3 to 5 [76.2 to 127], excl	3500 [24]
5 [127] and over	4500 [31]

TABLE 8
STRAIGHTNESS TOLERANCES

Specified OD (in.)	Specified wall thickness (in.)	Maximum curvature in any 3 ft (in.)	Maximum curvature in total length (in.)
Up to 5.0, incl.	Over 3% OD to 0.5, incl.	0.030	0.010 × length, ft
Over 5.0 to 8.0, incl.	Over 4% OD to 0.75, incl.	0.045	0.015 × length, ft
Over 8.0 to 12.75, incl.	Over 4% OD to 1.0, incl.	0.060	0.020 × length, ft

SPECIFICATION FOR CENTRIFUGALLY CAST AUSTENITIC STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

SA-451

(Identical with ASTM Specification A 451-93 except for editorial differences in 15.1.) 98

1. Scope

1.1 This specification covers austenitic alloy steel pipe for use in high-temperature, corrosive, or nuclear pressure service.

1.2 Several grades of austenitic stainless steel are covered as indicated in Table 1.

1.3 Optional supplementary requirements are provided when additional testing may be required.

1.4 The values stated in inch-pound units are to be regarded as the standard.

NOTE 1—This specification is not intended to cover centrifugal pipe made from alloys containing more than 0.20% carbon, such as are covered by Specification A 297.

2. Referenced Documents

2.1 *ASTM Standards:*

A 297 Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications

E 94 Guide for Radiographic Testing

E 165 Practice for Liquid Penetrant Inspection Method

E 186 Reference Radiographs for Heavy-Walled (2 to 4½ in. [51 to 114 mm] Steel Castings

E 280 Reference Radiographs for Heavy-Walled (4½ to 12 in. [114 to 305 mm] Steel Castings

E 446 Reference Radiographs for Steel Castings up to 2 in. [51 mm] in Thickness

2.2 *ANSI Standard:*

B46.1 Surface Texture

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for materials to this specification shall include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, metres or number of lengths),

4.1.2 Name of material (centrifugally cast pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (outside or inside diameter and minimum wall thickness in inches or millimetres),

4.1.5 Length (specific or random, Specification A 530/A 530M),

4.1.6 End Finish of Specification A 530/A 530M,

4.1.7 Optional Requirements (Section 10.4 and S1 through S7),

4.1.8 Test Report Required (Section 14), and

4.1.9 Special Requirements or Additions to Specification.

5. Materials and Manufacture

5.1 *Heat-Treatment*—The pipe shall receive a heat-treatment at the temperature and time specified in Table 2, followed by a quench in water or rapid cool by other means.

5.2 *Machining*—The pipe shall be machined on the inner and outer surfaces to a roughness value no greater than 250-μin. [6.35-μm] arithmetical average deviation (AA) from the mean line, as defined in American National Standard B46.1.

6. Chemical Analysis

6.1 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentage of elements specified in Table 1. The analysis shall be made on a test sample taken preferably during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1.

6.2 *Product Analysis*—A product analysis may be made by the purchaser. The sample for analysis shall be selected so as to be thoroughly representative of the pipe being analyzed. The chemical composition thus determined shall conform to the requirements specified in Table 1.

6.3 To determine conformance with the chemical analysis requirements, an observed value or calculated value shall be rounded in accordance with Practice E 29 to the nearest unit in the last right-hand place of values listed in Table 1.

7. Tensile Requirements

7.1 *Test Specimens:*

7.1.1 Test specimens shall be prepared in accordance with Test Methods and Definitions A 370. Test bars shall be poured in special blocks from the same heat as the castings represented. Test bars shall be supplied in sufficient number to furnish all specimens required in 7.2 and 7.3 (see Table 3).

7.1.2 Test specimens may be cut from heat-treated castings instead of from test bars when agreed upon between the manufacturer and the purchaser.

7.1.3 Tension test specimens shall be machined to the form and dimensions of the standard round 2 in. [50 mm] gage length specimens shown in Fig. 6 of Test Methods and Definitions A 370.

7.2 *Number of Tests:*

7.2.1 One tension test shall be made from each heat. The bar from which the test specimen is taken shall be heat-treated in the same manner as the castings represented.

7.2.2 If a specimen is machined improperly or flaws are revealed by machining or during testing, the specimen may be discarded and another substituted from the same heat. **98**

7.3 *Retests*—If the results of the mechanical tests for any heat do not conform to the requirements specified, the castings may be reheat-treated and retested, but may not be solution-treated more than twice.

8. Hydrostatic Test

8.1 Each length of pipe shall be hydrostatically tested in accordance with Specification A 530/A 530M.

8.2 It is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work has been performed on the casting. In such cases, the foundry is responsible for the satisfactory performance of the casting when it is tested.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free from cracks and hot tears. Other surface defects shall be judged in accordance with visual acceptance criteria which may be specified in the order.

10. Rework and Retreatment

10.1 Defects as defined in Section 9 shall be removed and their removal verified by visual inspection of the resultant cavities. Defects which are located by inspecting with Supplementary Requirements S6 or S7, or both, shall be removed or reduced to an acceptable size.

10.2 If removal of the defect does not infringe upon the minimum wall thickness, the depression may be blended uniformly into the surrounding surface.

10.3 If the cavity resulting from defect removal infringes upon the minimum wall thickness, weld repair is permitted subject to the purchasers' approval. The composition of the weld rod used shall be suitable for the composition of the metal being welded.

10.3.1 Only operators and procedures qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX, shall be used. All repair welds will be inspected to the same quality standards used to inspect the casting.

10.4 Postweld heat-treatment of the repaired casting is neither required nor prohibited.

11. Permissible Variations in Dimensions

11.1 *Thickness*—The wall thickness shall not vary over that specified by more than $\frac{1}{8}$ in. [3 mm]. There shall be no variation under the specified wall thickness.

12. Rejection

12.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the pipe may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

13. Rehearing

13.1 Samples that represent rejected material shall be preserved for 2 weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

14. Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

15. Product Marking

15.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the specification number, and grade. In addition, heat numbers, or serial numbers that are traceable to heat numbers, shall be marked on each length of pipe.

98

TABLE 1
CHEMICAL REQUIREMENTS

Grade	Composition, %										
	Carbon, max	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Columbium	Tantalum, max	Nitrogen
CPF3	0.03	1.50	0.040	0.040	2.00	8.0–12.0	17.0–21.0	...	...	...	...
CPF3A	0.03	1.50	0.040	0.040	2.00	8.0–12.0	17.0–21.0	...	...	...	...
CPF8	0.08	1.50	0.040	0.040	2.00	8.0–11.0	18.0–21.0	...	...	...	...
CPF8A	0.08	1.50	0.040	0.040	2.00	8.0–11.0	18.0–21.0	...	...	...	...
CPF3M	0.03	1.50	0.040	0.040	1.50	9.0–13.0	17.0–21.0	2.0–3.0	...	...	...
CPF8M	0.08	1.50	0.040	0.040	1.50	9.0–12.0	18.0–21.0	2.0–3.0	...	...	...
CPF10MC[A]	0.10	1.50	0.040	0.040	1.50	13.0–16.0	15.0–18.0	1.75–2.25	1.2 max, 10 × C min	...	...
CPF8C[A]	0.08	1.50	0.040	0.040	2.00	9.0–12.0	18.0–21.0	...	1 max, 8 × C min	...	...
CPF8C(Ta max)[B]	0.08	1.50	0.040	0.040	2.00	9.0–12.0	18.0–21.0	...	1 max, 8 × C min	0.10	...
CPH8	0.08	1.50	0.040	0.040	1.50	12.0–15.0	22.0–26.0	...	...	...	...
CPH20 or CPH10	0.20[C]	1.50	0.040	0.040	2.00	12.0–15.0	22.0–26.0	...	...	...	...
CPK20	0.20	1.50	0.040	0.040	1.75	19.0–22.0	23.0–27.0	...	...	...	...
CPE20N	0.20	1.50	0.040	0.040	1.50	8.0–11.0	23.0–26.0	...	...	...	0.08–0.20

[A] Grades CPF10MC and CPF8C may have a columbium plus tantalum content maximum of 1.35%.
[B] No designation as yet assigned by ASTM or Steel Founders Society of America.
[C] By agreement between the manufacturer and the purchaser, the carbon content of Grade CPH20 may be restricted to 0.10% max. When so agreed, the grade designation shall be CPH10.

TABLE 2
HEAT-TREATMENT REQUIREMENTS

Grade	Temperature, min		Hold Time, h/in. of Thickness
	°F	°C	
CPF3, CPF3A, CPF8, CPF8A, CPF3M, CPF8M	1900	1040	1
CPF10MC, CPF8C, CPF8C (Ta max)	1950	1065	2
CPH8, CPH10, CPH20, CPK20	2100	1150	1
CPE20N	2225	1218	1

TABLE 3
TENSILE REQUIREMENTS

Grade	Tensile Strength, min, ksi (MPa)	Yield Strength, min, ksi (MPa)	Elongation in 2 in. or 50 mm, min
CPF3	70 (485)	30 (205)	35
CPF3A[A]	77 (535)	35 (240)	35
CPF3M	70 (485)	30 (205)	30
CPF8	70 (485)	30 (205)	35
CPF8A[A]	77 (535)	35 (240)	35
CPF8M	70 (485)	30 (205)	30.0
CPF10MC	70 (485)	30 (205)	20.0
CPH10	70 (485)	30 (205)	30.0
CPF8C (Ta max), CPF8C	70 (485)	30 (205)	30.0
CPH8	65 (448)	28 (195)	30.0
CPK20	65 (448)	28 (195)	30.0
CPH20	70 (485)	30 (205)	30.0
CPE20N	80 (550)	40 (275)	30.0

[A] The properties shown are obtained by adjusting the composition within the limits shown in Table 1 to obtain a ferrite-austenite ratio that will result in the higher ultimate and yield strengths indicated. A lowering of impact values may develop in these materials when exposed to service temperature above 800°F.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Additional Tension Tests

S1.1 Additional tension tests shall be made at a temperature to be specified by the customer, and the properties to be met are a matter of agreement between purchaser and manufacturer.

S2. Flattening Test

S2.1 The flattening test shall be made on specimens from one or both ends of each length of pipe. If the specimen from any end of any length fails to conform to the requirements of Specification A 530/A 530M, that length shall be rejected.

S3. Photomicrographs

98 **S3.1** The manufacturer shall furnish one photomicrograph at 100 diameters from one specimen of as-finished pipe from each heat in one heat-treatment lot. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. Such photomicrographs are for information only, to show the actual metal structure of the pipe as furnished. No photomicrographs for the individual pieces purchased shall be required except as specified in Section S4.

S4. Photomicrographs for Individual Pieces

S4.1 The manufacturer shall furnish photomicrographs from one or both ends of each pipe. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S5. Metal Structure and Etching Tests

S5.1 Etching tests (Note 2) shall be made on transverse sections from the pipe and shall reveal the macrostructure of the material. Such tests are for information only.

NOTE 2—Pending development of etching methods applicable to the product covered by this specification, it is recommended that the Recommended Practice for a Standard Macroetch Test for Routine Inspection of Iron and Steel be followed.

S6. Radiographic Examination

S6.1 The castings shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with Guide E 94 and the types and degrees of discontinuities considered shall be judged by Reference Radiographs E 446, E 186, or E 280. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S7. Liquid Penetrant Examination

S7.1 The castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The method of performing the liquid penetrant test shall be in accordance with Practice E 165. The areas to be inspected, the methods and types of liquid penetrants to be used, the developing procedure, and the basis for acceptance shall be as specified on the inquiry or invitation to bid and on the purchase order or contract or both, or as agreed upon between the manufacturer and the purchaser.

SPECIFICATION FOR CENTRIFUGALLY CAST AUSTENITIC STEEL COLD-WROUGHT PIPE FOR HIGH-TEMPERATURE SERVICE

SA-452

(Identical with ASTM Specification A 452-88.)

1. Scope

1.1 This specification covers austenitic steel pipe made by the centrifugal casting process, subsequently cold worked, and given a recrystallizing anneal. Pipe ordered to this specification is suitable for use in high-pressure, high-temperature services and shall be suitable for bending and other forming operations and for fusion welding. Selection will depend on design, service conditions, mechanical properties, and high-temperature characteristics.

1.2 Several grades of austenitic steels are covered as given in Table 1.

1.3 Optional supplementary requirements (S1 through S8) are provided which call for additional tests and, when desired, shall be so stated in the purchase order together with the number of such tests required.

1.4 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 342 Test Methods for Permeability of Feebly Magnetic Materials

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 112 Methods for Determining Average Grain Size

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

2.2 *ANSI Standard:*

B46.1 Surface Texture

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 530, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material to this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, centimeters, or number of lengths),

4.1.2 Name of material (centrifugally cast cold-wrought pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (inside diameter and minimum wall thickness),

4.1.5 Length (specific or random) (Permissible Variations in Length Section of Specification A 530/A 530M),

4.1.6 End finish (Ends Section of Specification A 530/A 530M),

4.1.7 Optional requirements (and Sections 7, 10.3, and Sections S1 to S8, the Hydrostatic Test requirements of Specification A 530/A 530M),

4.1.8 Test report required (Certification Section of Specification A 530/A 530M),

4.1.9 Specification designation, and

4.1.10 Special requirements or exceptions to specification.

5. Materials and Manufacture

5.1 *Process*—The steel shall be made by the electric-furnace process and may incorporate separate degassing or refining.

5.2 *Manufacturing Practice:*

5.2.1 Material for subsequent cold working shall consist of centrifugally cast cylinders with ends cropped to the required length by a process that will not produce injurious defects in the wrought product.

5.2.2 The material shall be cold worked (at ambient temperature) by expansion, utilizing hydraulic or hydrostatic pressures, reduction between a mandrel and die as in cold drawing or rocking, reduction between die and hammers as in cold swaging, or any other cold-working process that results in sufficient plastic deformation in the material.

5.2.3 The material shall be adequately worked by one or more of the methods referred to in 5.2.2, with intermediate anneals as required, and brought as nearly as practicable to the finished shape and size by these methods. The amount of cold working shall be sufficient to produce, after the recrystallizing anneal, and average grain size no greater than ASTM Grain Size No. 1 as classified in Table 2 and shown in Plate 2 of Methods E 112.

5.3 *Machining:*

5.3.1 All pipe shall have both the inner and outer surfaces machined at some stage of manufacture.

5.3.2 The pipe shall be machined after heat treatment to a roughness value no greater than 250 μin. (6.4 μm) arithmetical average deviation (AA) from the mean line, terms as defined in ANSI B46.1. If the surface finish resulting from the cold-working method and preserved after heat treatment with suitable finishing treatment does not exceed 250 μin. (AA), machining may be omitted.

5.4 *Heat Treatment:*

5.4.1 Subsequent to final cold working, the pipe shall receive a solution heat treatment. The minimum solution temperature for Grade TP 347 H shall be 2000°F (1095°C), and for Grades TP 304 H and TP 316, 1800°F (980°F).

5.4.2 The heat-treatment procedure shall consist of heating the material to the minimum solution temperatures required and quenching in water or rapidly cooling by other means.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 The material within the prescribed chemical composition shall contain not more than 5% delta ferrite. The amount of delta ferrite contained in the material shall be determined by magnetic permeability measurements in accordance with Method 1, 2, or 3 of Test Methods A 342. Permeability measurements greater than 1.3 shall be cause for rejection of the material.

7. Product Analysis

7.1 At the request of the purchaser's inspector, an analysis of one semi-finished or finished pipe from each heat or two pipes from each lot (Note) shall be made by the manufacturer. A lot of pipe shall consist of the following:

Nominal Diameter, in.	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5, incl	200 or fraction thereof
6 and over	100 or fraction thereof

NOTE—A lot shall consist of the number of lengths, specified in Section 7 of the same size and wall thickness from any one heat of steel.

7.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 6.

7.3 If the analysis of one of the tests specified in this section does not conform to the requirement specified in Section 6 an analysis of each semi-finished or finished pipe or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

8.2 Tests for acceptance shall be made after the final heat treatment.

9. Permissible Variations in Dimensions

9.1 *Diameter*—For pipe under 4 in. (102 mm) in inside diameter, the inside diameter shall not vary under that specified by more than $\frac{1}{32}$ in. (0.8 mm). For pipe 4 in. (102 mm) in inside diameter and over, the inside diameter shall not vary under that specified by more than $\frac{1}{16}$ in. (1.6 mm). There shall be no variation over the specified inside diameter.

9.2 *Thickness*—The wall thickness shall not vary over that specified by more than 22% with a maximum of $\frac{1}{8}$ in. (3.2 mm). There shall be no variation under the specified wall thickness.

10. Finish

10.1 The finished pipe shall be reasonably straight and free of injurious defects. At the discretion of the inspector representing the purchaser, finished pipe shall be subject to rejection if surface defects acceptable under 10.4 are not scattered but appear over a large area in excess of what is considered a workmanlike finish.

10.2 *Depth of Injurious Defects*—Selected typical imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness, such defects shall be considered injurious.

10.3 *Repair by Welding*—Repair of injurious defects shall be permitted only subject to the approval of the purchaser. It is further understood that the composition of the welding rod shall be suitable for the composition of metal being welded, and the alloy content (chromium, nickel, molybdenum, and columbium) of the deposited weld metal shall conform to that required for the pipe. Defects shall be thoroughly chipped or ground out before welding. Only qualified operators and procedures in accordance with the *ASME Boiler and Pressure Vessel Code,* Section IX, shall be used. Full heat treatment in accordance with 5.4, shall follow welding. Local grinding following welding and retreatment shall have a finish whose roughness height is not greater than 250 μin. (6.4 μm), rms. (ANSI B46.1).

10.4 *Defects not Classified as Injurious*—Surface defects which do not encroach on the specified minimum wall thickness shall be removed either by machining or grinding, thereby blending the repaired surface with the surrounding unaffected surface area of the pipe and otherwise by equal in surface finish.

11. Grain Size

11.1 Photomicrographs at 100 diameters shall be furnished from one end of one length of pipe representing each heat and size in each heat treatment lot. Such photomicrographs shall be suitably identified as to pipe size (wall thickness and outside or inside diameter), piece number, and heat. Such photomicrographs shall shown grain size and are intended to show compliance with 5.2.3.

12. Specimens for Grain Size and Magnetic Permeability

12.1 Test specimens for the grain size examination shall be cut to reveal the pipe wall in cross section so as to make available outside diameter, midwall, and inside diameter locations for photomicrography. If separate specimens are cut to reveal these surface locations, they shall be so identified.

12.2 Test specimens for magnetic permeability measurements to determine delta ferrite content shall be in accordance with the applicable specimen requirements of Test Methods A 342. Apparatus to perform the magnetic permeability measurements shall be in accordance with the requirements of Test Methods A 342 whether individually constructed or obtained commercially.

13. Retests

13.1 If the results of the magnetic permeability measurements do not conform to the requirements of 6.2 the manufacturer may obtain two additional specimens from a location immediately adjacent to the first one for retest. If both of the two retested specimens pass the requirements, the material shall be acceptable.

14. Mechanical Tests Required

14.1 *Tension Test*—A test shall be made on specimens taken from one end of each length of pipe representing each heat in each heat treatment lot.

14.2 *Flattening Test*—A test shall be made on specimens from one end of each length of pipe.

14.3 *Magnetic Permeability*—Measurements specified in 6.2 shall be made on specimens from one end of one length of pipe representing each heat in each treatment lot.

14.4 *Grain Size*—The grain size shall be determined from one end of one length of pipe representing each heat and size in each heat treatment lot.

14.5 *Hydrostatic Test*—Each length of finished pipe shall be subjected to the hydrostatic test.

15. Inspection

15.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. When specified in the purchase order, the manufacturer shall notify the purchaser in time so that he may have his inspector present to witness any part of the manufacturer or tests that may be desired.

16. Product Marking

16.1 In addition to the marking prescribed in Specification A 530, the marking shall include wall thickness or schedule number, length, heat number or manufacturer's number by which the heat can be identified, an additional symbol "S" if the pipe conforms to the supplementary requirement specified in S1 to S8, followed by the number or numbers of supplementary paragraphs invoked. Indentation stamping, instead of stencilling, shall be permitted only with the purchaser's approval.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade TP 304H	Grade TP 347H	Grade TP 316H
Carbon	0.04–0.10	0.04–0.10	0.04–0.10
Manganese, max	2.00	2.00	2.00
Phosphorus, max	0.040	0.040	0.040
Sulfur, max	0.030	0.030	0.030
Silicon, max	0.75	0.75	0.75
Nickel	8.00–11.0	9.00–13.0	11.0–14.0
Chromium	18.0–20.0	17.0–20.0	16.0–18.0
Molybdenum	. . .	. . .	2.00–3.00
Columbium	. . .	[A]	. . .

[A] The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.00%.

TABLE 2
TENSILE REQUIREMENTS

All Grades and Sizes	ksi	MPa
Tensile strength, min	75	517
Yield strength, min	30	207
For Sizes 8 in. Nominal OD and Over		
	Longitudinal	Transverse
Elongation in 2 in. or 50 mm, min, %	45	45
Reduction of area, min, %	50	50
For Sizes Less Than 8 in. Nominal OD		
Elongation in 2 in. or 50 mm, min, %		
For walls $\frac{5}{16}$ in. (7.94 mm), and over in thickness, trip tests, and small sizes tested in full section	35	25
Standard round 2 in. or 50 mm gage length test specimen	30	20

SUPPLEMENTARY REQUIREMENTS FOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe 8 in. (203.2 mm) and over in nominal diameter. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530 and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A 530 shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of flattening test requirement that pipe shall be rejected subject to retreatment in accordance with Specification A 530 and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Grain Size

S4.1 Photomicrographs showing grain size shall be made from each length of pipe upon agreement between the manufacturer and purchaser. In this case, each photomicrograph shall be suitably identified as required in Section 11 and test specimens shall be selected as required in Section 12.

S5. Retest

S5.1 Retreatment of pipe, restricted to two retreatments, shall be retreated additionally with approval of the purchaser on the basis of satisfactory metallurgical evidence that the cause of the failure of the test is curable and the quality of the material is satisfactory.

S5.2 Upon the purchaser's request, retests shall be made from sections of material removed from any part of the pipe. Failure to meet the requirements stated in the body of this specification shall be cause of rejection.

S6. Etching Tests

S6.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S7. Hot Ductility Test (Test for Weldability)

S7.1 A high-temperature ductility test may be made upon each heat of material supplied in heavy-wall pipe sections. An appropriate specimen shall be heated to an initial temperature, cooled 100°F (56°C), then subjected to a tensile test and shall show a minimum reduction of area of 60%. The initial temperature is

that temperature 50°F (28°C) below the temperature at which the material exhibits zero ductility. Rejection of material shall not be based upon this test.

S8. Ultrasonic Test

S8.1 Each piece of pipe may be ultrasonically tested to determine its soundness throughout the entire length of the pipe. Each piece shall be ultrasonically tested in a circumferential direction in such a manner so that the entire piece is a scanned by the ultrasonic beam. The calibration standard shall be prepared from a section of pipe which has two notches, one in the inside surface and one in the outside surface, which are at least $1\frac{1}{2}$ in. (38 mm) long and have a depth of 3% of the wall thickness, or 0.004 in. (0.10 mm), whichever is greater. Any pipe showing an ultrasonic indication of greater amplitude than the amplitude of the indication from the calibration standard shall be subject to rejection.

SPECIFICATION FOR BOLTING MATERIALS, HIGH-TEMPERATURE, 50 TO 120 ksi [345 TO 827 MPa] YIELD STRENGTH WITH EXPANSION COEFFICIENTS COMPARABLE TO AUSTENITIC STEELS

SA-453/SA-453M

(Identical with ASTM Specification A 453/A 453M-94.) 98

1. Scope

1.1 This specification covers four grades of bolting materials with nine classes of yield strength ranging from 50 to 120 ksi [345 to 827 MPa] for use in high-temperature service such as fasteners for pressure vessel and valve flanges. The material requires special processing and is not intended for general purpose applications. The term "bolting material," as used in this specification, covers rolled, forged, or hot-extruded bars; bolts, nuts, screws, washers, studs, and stud bolts. Headed bolts and rolled threads may be supplied.

NOTE 1 — Other bolting materials are covered by Specification A 193/A 193M and Specification A 437/A 437M.

1.2 Supplementary Requirement S1 of an optional nature is provided. This shall apply only when specified by the purchaser in the order.

1.3 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 437/A 437M Specification for Alloy-Steel Turbine-Type Bolting Material Specially Heat Treated for High-Temperature Service

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition

E 139 Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

2.2 *ANSI Standards:*

ANSI B1.1 Unified Screw Threads

ANSI B18.2.1 Square and Hex Bolts and Screws Including Hex Cap Screws and Lag Screws

ANSI B18.2.2 Square and Hex Nuts

ANSI B18.3 Hexagon Socket and Spline Socket Screws

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 *bolting material* — this covers rolled, forged, or hot-extruded bars; bolts, nuts, screws, washers, studs, and stud bolts; and also includes those manufactured by upset heading or roll threading techniques.

3.1.2 *heat-treatment charge* — one heat of material heat treated in one batch. If a continuous operation is used, the weight processed as a heat-treatment charge shall not exceed the weights in Table 1.

3.1.3 *lot* — a lot shall consist of the quantities shown in Table 2.

4. Ordering Information

4.1 The inquiry and order shall indicate the following:

4.1.1 Quantity (weight or number of pieces),

4.1.2 Type of material (bars, bolts, nuts, etc.),

4.1.3 Grade and class,

4.1.4 Method of finishing (see 5.2),

4.1.5 Type of thread desired (see 5.2.2),

4.1.6 Alternative test method option (see 7.2.4.3),

4.1.7 Bolt shape option, if any (see 8.2),

4.1.8 Thread option, if any (see 8.3),

4.1.9 Test method for surface quality, if any (see Section 10),

4.1.10 Test location option, if any (Section 11),

4.1.11 Rejection option, if any (see 12.1), and

4.1.12 If stress-rupture testing is not required (see 7.2.1).

5. Materials and Manufacture

5.1 *Melting Process:*

5.1.1 The material shall be made by one or more of the following processes: electric-furnace, induction furnace, or consumable-electrode practice.

5.1.2 Vacuum, protective atmospheres, or protective slags may be used during melting or pouring of the heat.

5.2 *Finishing Process:*

5.2.1 The product shall be hot finished or cold finished (ground, rough turned or cold drawn) as specified on the purchase order.

5.2.2 Threads may be formed by machining or rolling. For Type 1 bolting, threading shall be performed after precipitation heat treatment. For Type 2 bolting, threading shall be performed after solution treatment but prior to precipitation heat treatment.

5.3 *Heat Treatment* — Each grade and class shall be heat treated as prescribed in Table 3.

6. Chemical Composition

6.1 *Heat Analysis* — An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Table 4. This analysis shall be made from a test sample taken during the pouring of the heat. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Table 4.

6.1.1 Steels with added lead shall not be used.

6.2 *Product Analysis:*

6.2.1 A product analysis may be made by the purchaser from tension samples representing the bolting material.

6.2.2 Samples for chemical analysis, except for spectro-chemical analysis, shall be taken in accordance with Practice E 59. The chemical composition thus determined shall conform to the requirements for product analysis variation as specified in Table 4.

6.2.3 A product analysis shall be made by the manufacturer of bar stock made from vacuum-arc remelted steel.

6.3 *Methods of Analysis* — For referee purposes, Test Methods E 30 shall be used.

7. Mechanical Properties

7.1 *Tension Test:*

7.1.1 *Requirements* — The material shall conform to the room-temperature tensile in each heat-treatment charge (Section 3).

7.1.2 *Number of Specimens:*

7.1.2.1 *Heat-Treated Bars* — When not more than two sizes of bars are heat treated in the same load, one tension test shall be made from each size in each heat of material in the heat-treatment charge (see 3.2). When more than two sizes of bars are treated in the same charge, one tension test shall be made from one bar of each of the two largest diameters from each heat of material in the heat-treating charge.

7.1.2.2 *Finished Parts* — One tension test shall be made if the lot consists of parts of the same nominal diameter. If the lot consists of parts of more than one nominal diameter, one tension test shall be made from each nominal diameter of each heat involved in the lot (Section 3).

7.1.2.3 The diameter range shall be in increments of ½ in. [12.5 mm].

7.1.2.4 Tension tests are not required on finished parts that are fabricated from heat-treated bars furnished in accordance with the requirements of this specification and tested in accordance with 7.1.2.1, provided they are not given a subsequent heat treatment.

7.1.3 *Test Location and Orientation* — Specimens shall be taken in accordance with Test Methods and Definitions A 370, Annex A1, from the bar stock used to make the product.

7.1.4 *Test Methods:*

7.1.4.1 The tension test specimen shall be machined to the form and dimensions prescribed in the latest issue of Test Methods and Definitions A 370.

7.1.4.2 The yield strength shall be determined by the offset method as described in the latest issue of Test Methods and Definitions A 370.

7.2 *Stress-Rupture Test:*

7.2.1 *Requirements* — The material shall conform to the stress-rupture requirements prescribed in Table 5 for design temperatures above 800°F [427°C]. Material not stress-rupture tested shall be permanently stamped NR.

7.2.2 The number of specimens shall be the same as the required number of tension test specimens.

7.2.3 The test location and orientation shall be the same as that required for the tension test specimens.

7.2.4 *Test Method:*

7.2.4.1 The rupture test shall be performed in accordance with Practice E 139.

7.2.4.2 A combination smooth and notched test specimen, machined to the dimensions prescribed in Fig. 1 and Table 6, shall be tested in accordance with the stress-rupture requirements prescribed in Table 5. The test shall be continued to rupture. The rupture shall occur in the smooth section of the bar.

7.2.4.3 As an alternative procedure and, when specifically approved by the purchaser, separate smooth and notched test specimens, machined from adjacent sections of the same piece, with gage sections conforming to the respective dimensions of Table 6, may be tested under the above conditions. The notched specimen need not be tested to rupture but shall not rupture in less time than the companion smooth specimen.

7.2.4.4 When the minimum specified time to rupture in Table 5 has been achieved, incremental loading may be used to accelerate the time to rupture. At intervals of 8 to 16 h, preferably 8 to 10 h, the stress shall be increased in increments of 5000 psi [34.5 MPa]. Rupture location, and elongation requirements shall be as prescribed in Table 5, 7.2.4.2, and 7.2.4.3.

7.3 *Hardness Test:*

7.3.1 *Requirements* — The material shall conform to the room temperature hardness requirements prescribed in Table 7.

7.3.2 *Number of Tests:*

7.3.2.1 *Bars 2 in. [50 mm] and Over* — One test on each mill-treated length.

7.3.2.2 *Bars under 2 in. [50 mm]* — One test per bar on at least 10% of the bars.

7.3.3 *Test Locations* — The hardness test shall be made at the center of the cross section for bars up to 1 in. [25 mm] in diameter, and at the midradius on bars 1 in. [25 mm] and larger in diameter.

7.3.4 *Test Method* — The test shall be performed in accordance with Test Methods and Definitions A 370.

8. Dimensions and Permissible Variations

8.1 Standard permissible variations in sizes of bars shall be as set forth in Table 8 for hot-rolled bars and in Table 9 for cold-finished bars.

8.2 Headed bolts shall be semi-finished, hexagonal in shape, and in accordance with the dimensions of ANSI B18.2.1. Nuts shall be hexagonal in shape, and in accordance with the dimensions of ANSI B18.2.2. Unless otherwise specified, the ANSI Standard heavy bolt and nut series shall be used. If socket head fasteners are required, the dimensions shall be in accordance with ANSI B18.3, as specified by the purchaser.

8.3 All bolts, stud bolts, and accompanying nuts, unless otherwise specified by the purchaser, shall be threaded in accordance with ANSI B1.1, Class 2A to 2B fit, or British Whitworth threads when specified.

8.4 Bolts, screws, studs and stud bolts shall be pointed. Points shall be flat and chamfered or rounded at option of the manufacturer. Length of point on studs and stud bolts shall be one to two complete threads as measured from the extreme end parallel to the axis. Length of studs and stud bolts shall be the threaded length and shall be measured from first thread to first thread.

9. Workmanship, Finish and Appearance

9.1 Finished parts shall have a workmanlike finish, maximum 63μin. [1.6μm] AA on the threads, body underhead fillet, and bearing area.

10. Workmanship and Quality Level Requirements

10.1 The material shall be uniform in quality and free of defects that would be detrimental to the intended service. Such defects may be determined by conventional test methods, as specified on the purchase order.

11. Inspection

11.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with the specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

12. Rejection and Rehearing

12.1 *Rejection* — Unless otherwise specified, any rejection based on tests made in accordance with this specification shall be reported to the manufacturer within 60 days from the receipt of the material by the purchaser. Material that shows injurious defects subsequent to its acceptance at the manufacturer's work will be rejected and the manufacturer shall be notified.

12.2 *Rehearing* — Specimens tested in accordance with this specification that represent rejected material shall be preserved for 2 months from the date of the test report. In case of dissatisfaction with the results of the test, the manufacturer may make claim for a rehearing within that time.

13. Certification

13.1 The producer's certification that the material was manufactured and tested in accordance with this specification together with a report of the test results shall be furnished at the time of shipment. The specification designation included on test reports shall include year of issue and revision letter, if any.

14. Product Marking

14.1 *Bars* — Each lift, bundle, or box shall be properly tagged with durable tags (metal, plastic, or equivalent), showing the heat number, type, condition, specification designation (A 453/A 453M), and size. The specification number marked on the material need not include specification year of issue and revision letter.

14.2 *Bolts, Nuts, Screws, Studs, and Steel Bolts* — Grade and manufacturer's identification symbols shall be applied to one end of studs $\frac{3}{8}$ in. [10 mm] in diameter and larger and to the heads of bolts $\frac{1}{4}$ in. [6 mm] in diameter and larger. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) In addition to the identification symbols (grade and class) shown in Table 2, the type designation 2 shall also appear on all roll-threaded bolting material so processed. Absence of the type designation number indicates Type 1 processed material or machine-cut threads.

14.3 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

98 **14.4** *Bar Coding* — In addition to the requirements in 14.1, 14.2, and 14.3, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard B-5 02.00. If used on small items, the bar code may be applied to the box or a substantially applied tag.

15. Keywords

15.1 marking; revision letter; year date

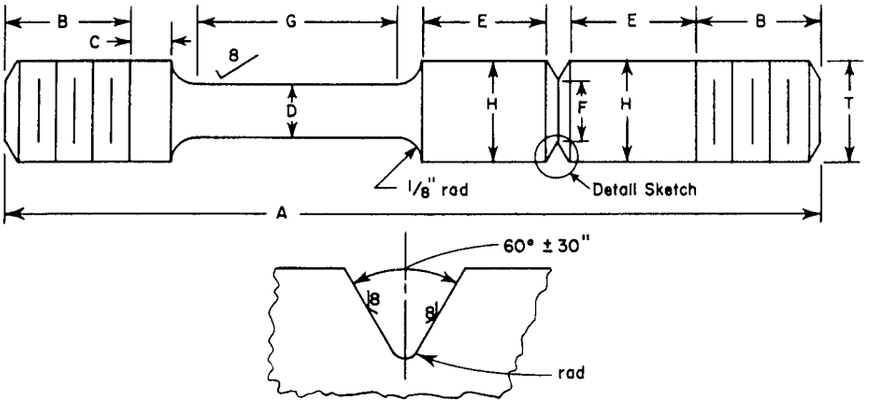


FIG. 1 COMBINATION SMOOTH-NOTCH STRESS-RUPTURE TEST SPECIMEN
(See Table 5)

TABLE 1
CONTINUOUS HEAT-TREATMENT CHARGE SIZES

Diameter, in. [mm]	Weight, lb [kg]
To 1¾ [44]	3000 [1400]
Over 1¾ [44] to 2½ [63]	6000 [2700]
Over 2½ [63]	12000 [5400]

TABLE 2
LOT SIZES

Diameter, in. [mm]	Maximum Lot Size, lb [kg]
1½ [38] and under	200 [90]
Over 1½ [38] to 1¾ [44], incl	300 [140]
Over 1¾ [44] to 2½ [63], incl	600 [270]
Over 2½ [63]	20 pieces

TABLE 3
HEAT TREATMENT REQUIREMENTS[A]

Grade	Class	Solution Treatment	Hardening Treatment
660	A	1650 ± 25°F [900 ± 14°C], hold 2 h, min, and liquid quench	1325 ± 25°F [720 ± 14°C], hold 16 h, air cool
	B	1800 ± 25°F [980 ± 14°C], hold 1 h, min, and liquid quench	1325 ± 25°F [720 ± 14°C], hold 16 h, air cool
	C	1800 ± 25°F [980 ± 14°C], hold 1 h, min, and oil quench	1425 ± 25°F [775 ± 14°C], hold 16 h, air cool 1200 ± 25°F [650 ± 14°C], hold 16 h, air cool
651	A		hot-cold worked at 1200°F [650°C] min with 15% min reduction in cross-sectional area, stress-relief anneal at 1200°F [650°C] min or 4 h, min
	B		hot-cold worked at 1200°F [650°C] min with 15% min reduction of cross-sectional area, stress-relief anneal at 1350°F [730°C] min for 4 h, min
662	A	1800 ± 25°F [980 ± 14°C], hold 2 h, liquid quench	1350 to 1400°F [730 to 760°C], hold 20 h, furnace cool to 1200 ± 25°F [650 ± 14°C], hold 20 h, air cool
	B	1950 ± 25°F [1065 ± 14°C], hold 2 h, liquid quench	1350 to 1400°F [730 to 760°C], hold 20 h, furnace cool to 1200 ± 25°F [650 ± 14°C], hold 20 h, air cool
665	A	1800 ± 25°F [980 ± 14°C], hold 3 h, liquid quench	1350 to 1400°F [730 to 760°C], hold 20 h, furnace cool to 1200 ± 25°F [650 ± 14°C], hold 20 h, air cool
	B	2000 ± 25°F [1095 ± 14°C], hold 3 h, liquid quench	1350 to 1400°F [730 to 760°C], hold 20 h, furnace cool to 1200 ± 25°F [650 ± 14°C], hold 20 h, air cool

[A] Times refer to the minimum time material is required to be at temperature.

TABLE 4
CHEMICAL REQUIREMENTS

	Grade 660		Grade 651	
	Content, %	Product Analysis Variation, Over or Under, %	Content, %	Product Analysis Variation, Over or Under, %
Carbon	0.08 max	0.01 over	0.28–0.35	0.02
Manganese	2.00 max	0.04	0.75–1.50	0.04
Phosphorus	0.040 max	0.005 over	0.040 max	0.005 over
Sulfur	0.030 max	0.005 over	0.030 max	0.005 over
Silicon	1.00 max	0.05	0.30–0.80	0.05
Nickel	24.0–27.0	0.20	8.0–11.0	0.15
Chromium	13.5–16.0	0.20	18.0–21.0	0.25
Molybdenum	1.00–1.50	0.05	1.00–1.75	0.05
Tungsten	. . .	. . .	1.00–1.75	0.05
Titanium	1.90–2.35	0.05	0.10–0.35	0.05 over
Columbium[A]	. . .	. . .	0.25–0.60	0.05
Aluminum	0.35 max	0.05 over	. . .	. . .
Vanadium	0.10–0.50	0.03	. . .	. . .
Boron	0.001–0.010	0.0004 under to 0.001 over	. . .	. . .
Copper	. . .	. . .	0.50 max	0.03 over

	Grade 662		Grade 665	
	Content, %	Product Analysis Variation, Over or Under, %	Content, %	Product Analysis Variation, Over or Under, %
Carbon	0.08 max	0.01 over	0.08 max	0.01 over
Manganese	0.40–1.00	0.03	1.25–2.00	0.04
Phosphorus	0.040 max	0.005 over	0.040 max	0.005 over
Sulfur	0.030 max	0.005 over	0.030 max	0.005 over
Silicon	0.40–1.00	0.05	0.10–0.80	0.05
Nickel	24.0–28.0	0.20	24.0–28.0	0.20
Chromium	12.0–15.0	0.15	12.0–15.0	0.15
Molybdenum	2.0–3.5	0.10	1.25–2.25	0.10
Titanium	1.80–2.10	0.05	2.70–3.3	0.05
Aluminum	0.35 max	0.05 over	0.25 max	0.05 over
Copper	0.50 max	0.03 over	0.25 max	0.03 over
Boron	0.001–0.010	0.0004 under to 0.001 over	0.01–0.07	0.005

[A] Or columbium plus tantalum.

TABLE 5
STRESS RUPTURE REQUIREMENTS

Grade	Class	Test Temperature, °F [°C]	Stress, min ksi	Stress, min MPa	Time to Rupture, min. h[A]	Elongation, min. %
660	A, B, and C	1200 [650]	56	385	100	5
651	A and B	1200 [650]	40	275	100	5
662	A and B	1200 [650]	55	380	100	5
665	A	1200 [650]	75	515	100	3
	B	1200 [650]	70	485	100	5

[A] The combination bar specimen shown in Fig. 1 shall be tested continuously at the temperature and at the minimum stress specified or at a greater stress and shall rupture in a time not less than that specified.

TABLE 6
TEST SPECIMEN DIMENSIONS

NOTE 1 — Surfaces marked ^{8}, finish to 8 μin. [0.2 μm] rms or better.

NOTE 2 — The difference between dimensions *F* and *D* shall not exceed 0.0005 in. [0.01 mm] for specimens 1 or 2. The difference shall not exceed 0.001 in. [0.02 mm] for specimens 3, 4, 5, or 6.

NOTE 3 — Taper the gage length *G* to the center so that the diameter *D* at the ends of the gage length exceeds the diameter at the center of the gage length by not less than 0.0005 in. [0.01 mm] nor more than 0.0015 in. [0.04 mm].

NOTE 4 — All sections shall be concentric about the specimen axis within 0.001 in. [0.02 mm].

NOTE 5 — Thread size *T* shall be equal to or greater than diameter *H*.

NOTE 6 — Dimensions *A* and *B* are not specified.

NOTE 7 — Length of shoulder *C* — $\frac{1}{8} + \frac{1}{32} - 0$ in. [3.2 + 0.8 mm].

NOTE 8 — Length of shoulder *E* — $\frac{3}{8} + \frac{1}{32} - 0$ in. [10.0 + 0.8 mm].

Specimen Type	Mid-length Gage Dia *D* and Notch-Root Dia *F*	Gage Length, *G*	Shoulder Diameter, *H*	Notch-Root Radius
	Inches			
1	0.125	0.5	0.177	0.005
2	0.160	0.65	0.226	0.005
3	0.178	0.75	0.250	0.005
4	0.252	1.0	0.375	0.007
5	0.357	1.5	0.500	0.010
6	0.505	2.0	0.750	0.015
Tolerance	±0.001	±0.05	±0.003	±0.0005
	Millimetres			
7	3.17	12.0	4.5	0.13
8	4.06	17.0	5.5	0.13
9	4.52	20.0	6.5	0.13
10	6.40	25.0	9.5	0.18
11	9.07	40.0	12.0	0.25
12	12.8	50.0	19.0	0.38
Tolerance	±0.025	±1.3	±0.1	±0.01

TABLE 7
MECHANICAL PROPERTY REQUIREMENTS

Grade	Class	Tensile Strength, min		Yield Strength (0.2% Offset), min		Elongation in 4 × Diam[A], min, %	Reduction of Area, min, %	Brinell Hardness Number	Approximate Rockwell Hardness, B and C	
		ksi	MPa	ksi	MPa				min	max
660	A, B, and C	130	895	85	585	15	18	248–341	99 HRB[D]	37 HRC
651	A	100	690	70[B]	485	18	35	217–277	95 HRB	29 HRC
				60[C]	415					
	B	95	655	60[B]	415	18	35	212–269	93 HRB	28 HRC[E]
				50[C]	345					
662	A	130	895	85	585	15	18	255–321	100 HRB[D]	35 HRC[E]
	B	125	860	80	550	15	18	248–321	99 HRB	35 HRC
665	A	170	1170	120	830	12	15	311–388	32 HRC	41 HRC
	B	155	1070	120	830	12	15	311–388	32 HRC	41 HRC

[A] See Fig. 6 of Test Methods and Definitions A 370.
[B] Material sizes 3 in. [76 mm] and under in diameter.
[C] Material sizes over 3 in. [76 mm] in diameter.
[D] Conversion numbers taken from Test Methods and Definitions A 370, Table 3D.
[E] Conversion numbers taken from Specification A 193/A 193M, Table 2 (austenitic steels); others by interpolation.

TABLE 8
PERMISSIBLE VARIATIONS IN SIZE OF HOT-ROLLED BARS

Specified Size	Permissible Variations from Specified Size, Over	Permissible Variations from Specified Size, Under	Out of Round
5/16 and under	0.005	0.005	0.008
Over 5/16 to 7/16, incl	0.006	0.006	0.009
Over 7/16 to 5/8, incl	0.007	0.007	0.010
Over 5/8 to 7/8, incl	0.008	0.008	0.012
Over 7/8 to 1, incl	0.009	0.009	0.013
Over 1 to 1 1/8, incl	0.010	0.010	0.015
Over 1 1/8 to 1 1/4, incl	0.011	0.011	0.016
Over 1 1/4 to 1 3/8, incl	0.012	0.012	0.018
Over 1 3/8 to 1 1/2, incl	0.014	0.014	0.021
Over 1 1/2 to 2, incl	1/64	1/64	0.023
Over 2 to 2 1/2, incl	1/32	0	0.023
Over 2 1/2 to 3 1/2, incl	3/64	0	0.035
Over 3 1/2 to 4 1/4, incl	1/16	0	0.046
Over 4 1/2 to 5 1/2, incl	5/64	0	0.058
Over 5 1/2 to 6 1/2, incl	1/8	0	0.070
Over 6 1/2 to 7 1/2, incl	5/32	0	0.085
Millimetres			
8.0 and under	0.13	0.13	0.20
Over 8.0 to 11.0, incl	0.15	0.15	0.23
Over 11.0 to 16.0, incl	0.18	0.18	0.25
Over 16.0 to 22.0, incl	0.20	0.20	0.30
Over 22.0 to 25.0, incl	0.23	0.23	0.33
Over 25.0 to 29.0 incl	0.25	0.25	0.38
Over 29.0 to 32.0, incl	0.28	0.28	0.41
Over 32.0 to 35.0, incl	0.30	0.30	0.46
Over 35.0 to 38.0, incl	0.35	0.35	0.53
Over 38.0 to 51,0, incl	0.40	0.40	0.58
Over 51.0 to 63.0, incl	0.80	0	0.58
Over 63.0 to 89.0, incl	1.2	0	0.89
Over 89.0 to 114, incl	1.6	0	1.2
Over 114 to 140, incl	2.0	0	1.5
Over 140 to 165, incl	3.2	0	1.8
Over 165 to 191, incl	4.0	0	2.2

TABLE 9
PERMISSIBLE VARIATIONS IN SIZE OF COLD-FINISHED BARS

Specified Size, in. [mm]	Permissible Variations from Specified Size, in. [mm][A] Over	Under
Over 1/2 to 1 [13 to 25], excl	0.002 [0.05]	0.002 [0.05]
1 to 1 1/2 [25 to 38], excl	0.0025 [0.06]	0.0025 [0.06]
1 1/2 to 4 [38 to 100], incl[B]	0.003 [0.08]	0.003 [0.08]

[A] When it is necessary to heat treat or heat treat and pickle after cold finishing, because of special hardness or mechanical property requirements, the permissible variations are generally double those shown in the table.

[B] For size tolerances of sizes over 4 in. [100 mm], the manufacturer should be consulted.

SUPPLEMENTARY REQUIREMENT

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, and order.

S1. Marking

S1.1 Grade and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts and studs smaller than $\frac{1}{4}$ in. [6 mm] in diameter and for $\frac{1}{4}$ in. [6 mm] studs requiring more than a total of three symbols, the marking shall be a matter of agreement between the purchaser and the manufacturer.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, HIGH-STRENGTH MANGANESE

SA-455/SA-455M

(Identical with ASTM Specification A 455/A 455M-90) 98

1. Scope

1.1 This specification covers high-tensile strength carbon-manganese steel plates intended for welded pressure vessels.

1.2 This material is usually made to a semi-killed or capped deoxidation practice. However, at the purchaser's or the producer's option, the material may be made silicon-killed or aluminum-killed.

1.3 The maximum thickness of plates furnished under this specification shall be $\frac{3}{4}$ in. [20 mm].

1.4 The values stated in either inch-pound units or SI are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Applicable Document

2.1 *ASTM Standard:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements, two supplementary requirements are available to meet end use requirements as follows:

3.3.1 Simulated post-weld heat treatment of test coupons, and

3.3.2 Bend test.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Heat Treatment

4.1 Plates are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5. Chemical Requirements

5.1 The steel shall conform to the chemical requirements shown in Table 1.

6. Mechanical Requirements

6.1 *Tension Test Requirements*—The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

98

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %
Carbon, max[A,B]	0.33
Manganese:	
Heat analysis	0.85–1.20
Product analysis	0.79–1.30
Phosphorus, max[A]	0.035
Sulfur, max[A]	0.035
Silicon[C]:	
Heat analysis	0.10 max
Product analysis	0.13 max

[A] Applies to both heat and product analyses.
[B] When the silicon is higher than 0.10%, the carbon maximum shall be 0.28%.
[C] At the purchaser's or the producer's option, silicon may be 0.40% max on heat analysis, 0.45% max on product analysis.

98

TABLE 2
TENSILE REQUIREMENTS

	Thickness		
	Up to 0.375 in. [9.5 mm]	Over 0.375 to 0.580 in. [15 mm]	Over 0.580 to 0.750 in. [20 mm]
Tensile strength, ksi [MPa]	75–95 [515–655]	73–93 [505–640]	70–90 [485–620]
Yield strength, min, ksi [MPa]	38 [260]	37 [255]	35 [240]
Elongation in 8 in. [200 mm], min, %	15[A]	15[A]	15[A]
Elongation in 2 in. [50 mm], min, %	22	22[A]	22[A]

[A] See Specification A 20/A 20M for elongation adjustments.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order. A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons, and

S14. Bend Test.

SPECIFICATION FOR DUCTILE IRON CASTINGS FOR PAPER MILL DRYER ROLLS

SA-476

(Identical with ASTM Specification A 476-90 except for editorial differences in 4.1)

1. Scope

1.1 This specification covers ductile iron castings for use in pressure containing paper mill dryer rolls at temperatures up to 450°F.

1.2 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron (see Appendix X1).

1.3 A complete metric companion to Specification A 476 has been developed—A 476M; therefore, no metric equivalents are presented in this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 644 Terminology Relating to Iron Castings
E 8 Test Methods of Tension Testing of Metallic Materials
E 10 Test Method for Brinell Hardness of Metallic Materials
E 94 Guide for Radiographic Testing
E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness

3. Terminology

3.1 Definitions for many terms common to iron castings are found in Terminology A 644.

4. Ordering Information

4.1 Orders for material purchased to the requirements of this specification shall include the following information:

4.1.1 Quantity,

4.1.2 Specification number and date of issue,

4.1.3 Description of casting by pattern number or drawing,

4.1.4 Heat treatment, if required (see 5.1),

4.1.5 Type of test coupon (see 9.2),

4.1.6 Certification, if required (see 13.1),

4.1.7 Marking location (see 14.1), and

4.1.8 Additional requirements.

5. Heat Treatment

5.1 The castings may be stress relieved at a temperature not to exceed 1200°F.

6. Chemical Requirements

6.1 The castings shall conform to the following chemical requirements:

Total carbon, min, %	3.0
Silicon, max, %	3.0
Phosphorus, max, %	0.08
Sulfur, max, %	0.05

6.2 The castings shall have a carbon equivalent of 3.8 to 4.5 inclusive.

NOTE—The carbon content equivalent is calculated as follows:
Total carbon + 0.3 (silicon + phosphorus)

6.3 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or on thin wafers approximately $\frac{1}{32}$ in. thick, cut from test coupons. Drillings shall not be used due to attendant loss of graphite.

7. Mechanical Properties

7.1 The iron represented by test coupons shall conform to tensile requirements prescribed in Table 1.

7.2 The yield strength prescribed in Table 1 may be determined by any of the approved procedures described in 7.3 of Test Methods E 8.

7.3 The Brinell hardness of the material shall be minimum of 201 HB. Hardness tests shall be conducted in accordance with Test Method E 10, using a 3000-kgf load. The test may be made on either the casting or on the test coupon representing the casting.

8. Workmanship, Finish, and Appearance

8.1 The castings shall conform to the dimensions on the drawings furnished by the purchaser, or if no drawing has been provided, to the dimensions predicated by the pattern supplied by the purchaser. Surfaces of the castings shall be free of adhering sand. Runners, risers, fins, and other extraneous metal shall be removed.

9. Sampling

9.1 Test coupons shall be poured from the same iron as the castings represented.

9.2 Test coupons shall be cast either to the "Y" block size and shape shown in Fig. 1 or to the dimensions of the 1 in. keel block shown in Fig. 2. The type of test coupon and, when selected, the size of the "Y" block shall be specified by the purchaser.

9.3 The test coupons shall be cast in open molds made of suitable core sand with a minimum $1\frac{1}{2}$ in. of sand for the 1 in. size and 3 in. of sand for the 3 in. size. The coupons shall be left in the mold until black.

9.4 Table 2 shows the equivalent geometrical shapes with various dimensions and the equivalent "Y" block, based on cooling rates, and may be used as a guide for selection of the proper "Y" block to be specified to represent the casting.

9.5 When the castings are heat treated, the test coupons shall be heat treated with the castings they represent.

10. Tension Test

10.1 Tension test specimens shall be obtained from test coupons shown in either Fig. 1 or Fig. 2, and machined to the dimensions shown in Fig. 3. Test coupons cast as 'Y' blocks (Fig. 1) shall be sectioned as shown in Fig. 4.

10.2 One tension test shall be performed for each casting.

10.3 If any specimen shows defective machining or flaws, it may be discarded and another substituted from the same casting represented.

10.4 If an apparently sound test specimen fails to conform to the tensile requirements, two retests may be made. If either retest fails to conform to the requirements specified, the castings shall be rejected.

11. Repairs

11.1 Castings made to this specification that leak on subsequent hydrostatic testing may be repaired by using threaded plugs provided the following requirements are met.

11.1.1 No welding or brazing shall be permitted.

11.1.2 The diameter of the plug shall not exceed the diameter of a standard 2 in. iron pipe size pipe plug.

11.1.3 The plugs, where practical, shall conform in all dimensions to the standard iron pipe size pipe plugs. In addition, they shall have full thread engagement corresponding to the thickness of the repaired section. Where a tapered plug is impractical because of excess wall thickness in terms of plug diameter and coincident thread engagement, other types of plugs may be used provided both full thread engagement and effective sealing against pressure are obtained. Where possible the ends of the plugs should be ground smooth after installation to conform to the inside and outside contours of the cylinder.

11.1.4 The material from which the plug is manufactured shall conform in all respects to this specification.

11.1.5 The area adjacent to the drilled hole should be examined radiographically in accordance with Guide E 94. The area examined shall meet the requirements of Severity Level 3 of Reference Radiographs E 446.

11.1.6 The thickness of any repaired section in relation to the size of plug used shall be not less than that given in Table 3.

11.1.7 The minimum radius of curvature of the repaired section of the cylinder in relation to the size of plug used shall be not less than that given in Table 4.

11.1.8 A repaired area may consist of a maximum of three plugs with a spacing such that the distance between adjacent plugs shall not be less than those listed in Table 5. Adjacent areas of repair, in which each contains more than one plug, shall be separated by at least twice the distance required in Table 5 for the two nearest plugs separating the two areas.

11.2 Surface imperfections not exceeding 20% of the thickness of the section and other minor defects may be repaired by plugging provided the diameter of the plug does not exceed its length.

12. Inspection

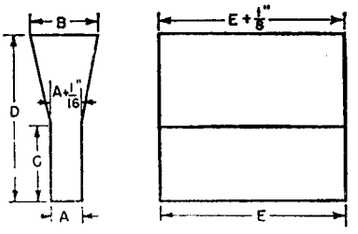
12.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with this specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture unless otherwise agreed.

13. Certification

13.1 When specified in the order, the manufacturer's certification shall be furnished stating that the material was manufactured, sampled, tested, and inspected in accordance with the requirements of this specification and was found to meet the requirements. In addition to the certification, a test report shall be furnished showing the results of all tests performed.

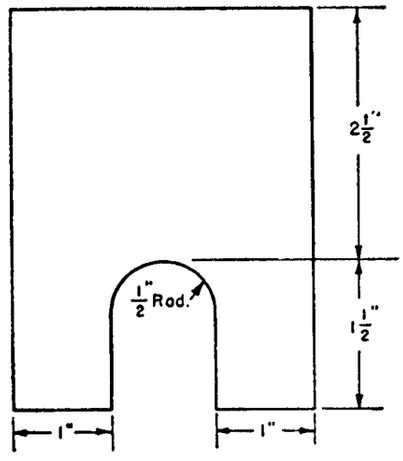
14. Product Marking

14.1 Castings made in accordance with this specification shall have the name of the manufacturer or his recognized trade mark and this specification number cast on or indelibly stamped on the surface designated by the purchaser.



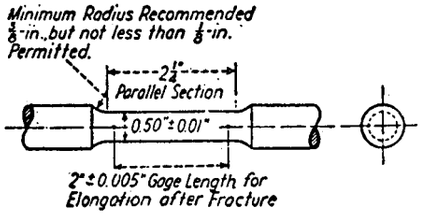
Dimensions	"Y" Block Size	
	For Castings of Thickness ½ in. to 1½ in.	For Castings of Thickness of 1½ in. and Over
	in.	in.
A	1	3
B	1⅛	5
C	3	4
D	6	8
E	7 approx	7 approx

FIG. 1 "Y" BLOCKS FOR TEST COUPONS



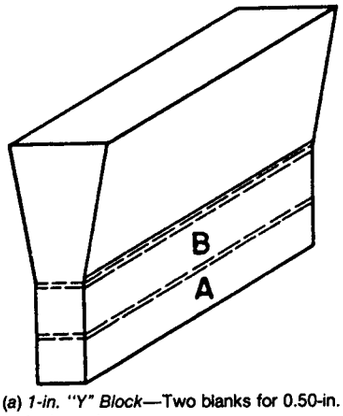
NOTE—The length of keel block shall be 6 in.

FIG. 2 KEEL BLOCK FOR TEST COUPONS

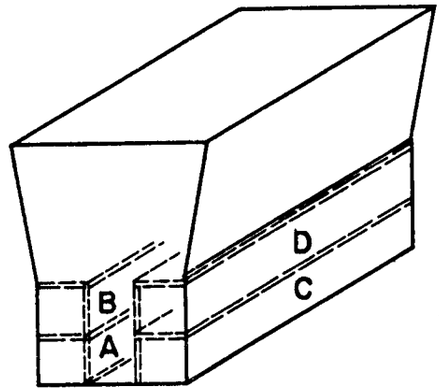


NOTE—The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. larger in diameter than the center.

FIG. 3 STANDARD ROUND TENSION TEST SPECIMEN WITH 2-IN. GAGE LENGTH



(a) *1-in. "Y" Block*—Two blanks for 0.50-in. diameter tension test specimens.



(b) *3-in. "Y" Block*—Four blanks for 0.50-in. diameter tension test specimens.

FIG. 4 SECTIONING PROCEDURE FOR "Y" BLOCKS

TABLE 1
TENSILE REQUIREMENTS

Test Coupon Section Thickness	1 in.	3 in.
Tensile strength, min, ksi	80	80
Yield strength, min, ksi	60	60
Elongation in 2 in., min, %	3.0	1.0

TABLE 2
EQUIVALENT GEOMETRIC SHAPES CORRESPONDING TO "Y" BLOCKS

"Y" Block Size, in.	Infinite Plate Thickness, in.	Round Diameter, in.	Cube Edge, in.
1	0.9	1.75	2.75
3	1.6	3.1	4.8

TABLE 3
MINIMUM THICKNESS OF REPAIRED SECTIONS

Iron Pipe Size Plug, in.	Minimum Section Thickness, in.
1/8	11/32
1/4	7/16
3/8	1/2
1/2	21/32
3/4	3/4
1	13/16
1 1/4	7/8
1 1/2	15/16
2	1

TABLE 4
MINIMUM RADIUS OF REPAIRED SECTIONS

Iron Pipe Size Plug, in.	Minimum Radius of Curvature, in.
1/8	9/16
1/4	11/16
3/8	1 1/16
1/2	1 1/4
3/4	2
1	2 1/2
1 1/4	4
1 1/2	5 1/4
2	8 1/8

TABLE 5
MINIMUM DISTANCE BETWEEN PLUG CENTERS
(Based on Ligament Efficiency of 80%)

Adjacent Plug Diameters, in.	Minimum Distance Between Plug Centers, in.			
	1/8, 1/4, 3/8	1/2, 3/4	1, 1 1/4	1 1/2, 2
1/8, 1/4, 3/8	2 5/8	4 1/8	6 5/8	9 1/2
1/2, 3/4	4 1/8	4 1/8	6 5/8	9 1/2
1, 1 1/4	6 5/8	6 5/8	6 5/8	9 1/2
1 1/2, 2	9 1/2	9 1/2	9 1/2	9 1/2

Example — Assume three plugs are required for repair, one 1/8 in., one 3/8 in., and one 1 1/2 in. The minimum distance permitted is as follows.

Ligament distance between 1/8 and 3/8 in. plugs = 2 5/8 in.
Ligament distance between 1/8 and 1 1/2 in. plugs = 9 1/2 in.
Ligament distance between 3/8 and 1 1/2 in. plugs = 9 1/2 in.

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of iron castings are influenced by the cooling rate during and after solidification, by chemical composition, by heat treatment, by the design of the casting, by the design and nature of the mold, by the location and effectiveness of gates and risers, and by certain other factors.

X1.2 The cooling rate in the mold and, therefore, the properties developed in any particular section are influenced by the presence of cores, chills and chaplets, changes in section thickness, and the existence of bosses, projections, and intersections, such as junctions of ribs and bosses. Because of the complexity of the interactions of these factors, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be more closely ascertained by appropriate experimentation.

X1.3 When reliable information is unavailable on the relationship between properties in a casting and those in a separately cast test specimen, and when experimentation would be unfeasible, the size of the test casting should be so selected as to approximate the thickness of the main or controlling section of the casting.

SPECIFICATION FOR STAINLESS STEEL BARS AND SHAPES FOR USE IN BOILERS AND OTHER PRESSURE VESSELS

SA-479/SA-479M

(Identical with ASTM Specification A 479/A 479M-95b except for a new para. 5.1.2 clarifying the heat treatment requirements, new paras. 7.4 and 11.1.2.1, and editorial differences in Table 2.) 98

1. Scope

1.1 This specification covers hot- and cold-finished bars of stainless steel, including rounds, squares, and hexagons, and hot-rolled or extruded shapes such as angles, tees, and channels for use in boiler and pressure vessel construction.

NOTE 1 — There are standards covering high nickel, chromium, austenitic corrosion, and heat-resisting alloy materials. These standards are under the jurisdiction of ASTM Subcommittee B02.07 and may be found in *Annual Book of ASTM Standards,* Vol. 02.04.

1.2 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standards; within the text and tables, the SI units are shown in [brackets]. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 112 Test Methods for Determining the Average Grain Size

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *Other Document:*

SAE J1086 Recommended Practice for Numbering Metals and Alloys

3. Ordering Information

3.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

3.1.1 Quantity (weight or number of pieces),

3.1.2 Dimensions, including diameter or thickness (and width), shape or form, applicable prints or sketches, length, etc.,

3.1.3 Type or UNS designation (Table 1),

3.1.4 ASTM designation and edition year if other than latest edition,

3.1.5 Heat treated condition (Section 5),

3.1.6 Finish (see Manufacture section of Specification A 484/A 484M).

3.1.7 Supplementary Requirements invoked for special services (described at the end of this specification):

3.1.8 Whether bars are to be rolled as bars or cut from strip or plate,

3.1.9 Preparation for delivery (see Preparation for Delivery section of Specification A 484/A 484M),

3.1.10 Marking requirements (see Marking section of Specification A 484/A 484M).

3.1.11 Surface preparation of shapes (see Manufacture section of Specification A 484/A 484M),

3.1.12 The intended use of the material, if the purchaser considers this useful information.

NOTE 2 — A typical ordering description is as follows: 5000 lb [2000 kg]; 1.000 in. [25 mm] round bar by 10 to 12 ft [3 or 4 m]; Type 304 or UNS S30400; to Specification A 479 [A 479M]; annealed; centerless ground; plus any optional supplementary requirements; such as, for example, special marking instructions.

4. General Requirements

4.1 In addition to the requirements of the specification, all requirements of the current editions of Specification A 484/A 484M shall apply. Failure to comply with the general requirements of Specification A 484/A 484M constitutes nonconformance with this specification.

5. Heat Treatment

5.1 *Austenitic Grades:*

5.1.1 Except for the strain-hardened grade (see 5.1.3), and the hot-rolled grade (see 5.1.4), all austenitic grades of stainless steel shall be furnished in the solution annealed condition, with subsequent light cold drawing and straightening permitted (see Supplementary Requirement S5 if annealing must be the final operation). Solution annealing for all grades, except the H grades (see 5.1.2), S31254 (see 5.1.5), S24565 (see 5.1.6), and S35315 (see 5.1.8), shall consist of (1) heating the material to a temperature of 1900°F [1040°C] minimum so that grain boundary carbides enter into solution, and cooling rapidly to prevent grain boundary carbide precipitation; or alternatively (2) (except for the columbium and titanium stabilized grades 309Cb, 310Cb, 316Cb, 316Ti, 321, 347, and 348) immediately following hot working while the temperature is above 1750°F [955°C] so that grain boundary carbides are in solution, cooling rapidly to prevent grain boundary carbide precipitation. When Supplementary Requirement S2 is invoked, all austenitic grades except S30815 shall pass the intergranular corrosion test requirements described in S2.

5.1.2 For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. For H grades, the minimum solution annealing temperatures shall be as follows:

5.1.2.1 When hot finished, 1900°F [1040°C] for Types 304H, 309H, 310H, and 316H; 1925°F [1050°C] for Types 321H, 347H, and 348H.

5.1.2.2 When cold worked prior to solution annealing, 1900°F [1040°C] for Types 304H, 309H, 310H, and 316H; 2000°F [1095°C] for Types 321H, 347H, and 348H.

NOTE 3 — Solution annealing temperatures above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in the stabilized grades, Types 321, 321 H, 347, 347 H, 348 and 348 H. When intergranular corrosion is of concern, the purchaser should specify the corrosion test of S2 (to be conducted on sensitized specimens). The manufacturer may, if necessary, use a lower temperature resolution anneal or a stabilization anneal after a high temperature solution anneal in order to meet corrosion test requirements. Consideration should be given to the corrosive media before using a stabilization anneal at less than 1800°F [980°C], as such a treatment may not be fully effective for all media.
NOTE 4 — Grain size requirements for the H grades are described in Section 7.

5.1.3 *Strain Hardened Austenitic Type 316* — When Type 316 is desired with increased mechanical properties, the strain hardened condition may be specified and is produced by solution annealing, as described in 5.1.1, followed by strain hardening sufficient to meet the required mechanical properties. Solution annealed and strain hardened material shall be capable of meeting the intergranular corrosion test of Supplementary Requirement S2.

5.1.3.1 Two strain hardened conditions have been established for different applications: Level 1 and Level 2 (see the Mechanical Property Requirements table).

5.1.4 High tensile Type XM-19 shall be in the hot-rolled or strain-hardened condition and shall be capable of meeting the mechanical property requirements of the Mechanical Property Requirements table and passing the intergranular corrosion test prescribed in S2. The strain hardened condition is achieved by solution annealing followed by cold working sufficient to develop the required mechanical properties.

5.1.5 Solution annealing of S31254 shall consist of heating the material to a temperature of 2100°F [1150°C] minimum, for an appropriate time followed by water quenching or rapidly cooling by other means.

5.1.6 Solution annealing of S24565 shall consist of heating the material in the range of temperature from 2050°F [1120°C] to 2140°F [1170°C] for an appropriate time, followed by water quenching or rapidly cooling by other means.

5.1.7 Solution annealing of S33228 shall consist of heating the material in the temperature range 2050 to 2160°F [1120 to 1180°C] for an appropriate time followed by water quenching or rapid cooling by other means.

5.1.8 Solution annealing of S35315 shall consist of heating the material to a temperature of 2100°F [1150°C] minimum, for an appropriate time followed by water quenching or rapidly cooling by other means.

5.2 *Austenitic-Ferritic Grades:*

5.2.1 S31803 and S32550 shall be furnished in the annealed condition with subsequent straightening permitted. The annealing treatment of S31803 and S32550 shall consist of heating the material to a temperature of 1900°F [1040°C] minimum for an appropriate time followed by water quenching or rapid cooling by other means.

5.2.2 S32950 shall be annealed by heating the material to a temperature of 1825°F [995°C] to 1875°F [1025°C] for an appropriate time followed by water quenching or rapid cooling by other means.

5.2.3 S32750 shall be annealed by heating the material to a temperature of 1880°F [1025°C] to 2060°F [1125°C] for an appropriate time followed by water quenching or rapid cooling by other means. Subsequent straightening shall be permitted.

5.2.4 S39277 shall be annealed by heating the material to 1940°F [1060°C] to 2060°F [1125°C] for an appropriate time followed by water quenching or rapid cooling by other means. Subsequent straightening shall be permitted.

5.3 *Ferritic Grades* — Ferritic grades shall be annealed to meet the requirements of the Mechanical Property Requirements table.

5.4 *Martensitic Grades:*

5.4.1 All grades of martensitic steels shall be supplied in either the annealed condition or in the tempered condition as specified by the purchaser (see 3.1.3). Tempered material shall be normalized, or shall be liquid quenched from 1700°F [925°C], minimum, followed by tempering in accordance with 5.4.2, 5.4.3, or 5.4.4.

5.4.2 Types 403 and 410 tempered material shall be held at tempering temperature for at least 1 h/in. (25.4 mm) of cross section as follows:

5.4.2.1 *Condition 1* — 1250°F [675°C] minimum, 1400°F [760°C] maximum.

5.4.2.2 *Condition 2* — 1100°F [595°C] minimum, 1400°F [760°C] maximum.

5.4.2.3 *Condition 3* — 1050°F [565°C] minimum, 1400°F [760°C] maximum.

5.4.3 Types XM-30, 414, and 431 tempered materials shall be held at 1100°F [595°C], minimum, for at least 1 h/in. [25 mm] of cross section. Maximum tempering temperature shall be 1400°F [760°C].

5.4.4 For S41500 heat to 1750°F [955°C] minimum, air cool to 200°F [95°C] or lower prior to any optional intermediate temper and prior to the final temper. The final temper shall be between 1050°F [565°C] and 1150°F [620°C].

5.4.5 When the purchaser elects to perform the hardening and tempering heat treatment, martensitic materials shall be supplied by the manufacturer in the annealed condition (see 5.4.1). In this case it shall be the purchaser's responsibility to apply the proper heat treatment and to conduct the tests he deems necessary to assure that the required properties are obtained.

6. Chemical Composition

6.1 Chemical composition shall be reported to the purchaser, or his representative, and shall conform to the requirements specified in Table 1.

6.2 When a product analysis is performed or requested by the purchaser, the tolerance limits as described in Specification A 484/A 484M apply unless Supplementary Requirement S3 is invoked.

6.3 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

7. Grain Size for Austenitic Grades

7.1 All austenitic grades shall be tested for average grain size by Test Methods E 112.

7.2 The H grades shall conform to an average grain size as follows:

7.2.1 ASTM No. 6 or coarser for Types 304H, 309H, 310H, and 316H,

7.2.2 ASTM No. 7 or coarser for Types 321H, 347H, and 348H.

7.3 For S32615, the grain size as determined in accordance with Test Methods E 112, comparison method, Plate 11, shall be No. 3 or finer.

98 **7.4** For ASME Code applications for services above 1000°F (540°C), all materials must meet the requirements of the corresponding H grades including chemistry, annealing temperature and grain size.

8. Mechanical Properties Requirements

8.1 The material shall conform to the mechanical property requirements specified in Table 2 for the grade ordered. At least one room-temperature test shall be performed by the manufacturer on a sample from at least one bar or shape from each lot of material.

8.2 The yield strength shall be determined by the offset (0.2%) method as prescribed in Test Methods and Definitions A 370.

8.3 Martensitic material supplied in the annealed condition shall be capable of meeting the hardened and tempered mechanical properties when heat treated in accordance with the requirements of 5.4.

8.4 Hardness measurements, when required, shall be made at a location midway between the surface and the center of the cross section.

8.5 Martensitic grades shall be capable of meeting the hardness requirements after heat treating as specified in Table 3.

9. Corrosion Testing

9.1 Austenitic stainless steels solution annealed by the alternative method (see (2) in 5.1.1) shall be tested and pass the intergranular corrosion test requirements described in S2.

10. Certification

10.1 The material manufacturer's certificate of compliance certifying that the material was manufactured and tested in accordance with this specification, together with a report of the results required by this specification and the purchase order shall be furnished at the time of shipment. The certification shall be positively relatable to the lot of material represented.

11. Product Marking

11.1 In addition to the marking requirements of Specification A 484/A 484M, materials which have been heat treated in accordance with 5.1, 5.2, 5.3, 5.4 or have been strain hardened in accordance with 5.1.3 shall be identified by placement of the following symbols after the grade designation:

11.1.1 *Austenitic Grades:*

11.1.1.1 All grades in the annealed condition — A,

11.1.1.2 Strain hardened Type 316, Level 1 — S1,

11.1.1.3 Strain hardened Type 316, Level 2 — S2,

11.1.1.4 Hot-rolled Type XM-19 — H,

11.1.1.5 Strain hardened Type XM-19 — S,

11.1.1.6 Material meeting Supplementary Requirement S1 — ELT (unnecessary for H grades).

11.1.2 *Austenitic-Ferritic Grades* — All grades in the annealed condition — A.

11.1.2.1 In addition to other marking requirements of this specification, all grades in the direct quenched annealed condition of ASME Code application above 1000°F (540°C) marking shall be — D. 98

11.1.3 *Ferritic Grades* — All grades in the annealed condition — A.

11.1.4 *Martensitic Grades:*

11.1.4.1 All grades in the annealed condition — *A.*

11.1.4.2 Types 403 and 410 — COND 1, COND 2, or COND 3 as appropriate for the tempering temperature employed.

11.1.4.3 Type 414, S41500, and Type XM-30 tempered materials — T.

12. Keywords

12.1 austenitic stainless steel; austenitic-ferritic duplex stainless steel; ferritic stainless steel; martensitic stainless steel; pressure containing parts; pressure vessel service; stainless steel bars; stainless steel shapes; temperature service applications — high

TABLE 1
CHEMICAL REQUIREMENTS

UNS Designation [Note (1)]	Type	Composition, %									
		Carbon, max [Note (2)]	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Chromium	Nickel	Nitrogen, max [Note (2)]	Molybdenum	Other Elements [Note (3)]
Austenitic Grades											
S20161	...	0.15	4.00–6.00	0.040	0.040	3.00–4.00	15.00–18.00	4.00–6.00	0.08–0.20	...	...
S20910	XM-19	0.06	4.00–6.00	0.040	0.030	1.00	20.50–23.50	11.50–13.50	0.20–0.40	1.50–3.00	Cb 0.10–0.30; V 0.10–0.30
S21600	XM-17	0.08	7.50–9.00	0.045	0.030	1.00	17.50–22.00	5.00–7.00	0.25–0.50	2.00–3.00	...
S21603	XM-18	0.03	7.50–9.00	0.045	0.030	1.00	17.50–22.00	5.00–7.00	0.25–0.50	2.00–3.00	...
S21800	...	0.10	7.00–9.00	0.060	0.030	3.5–4.50	16.00–18.00	8.00–9.00	0.08–0.18	...	...
S21904	XM-11	0.04	8.00–10.00	0.060	0.030	1.00	19.00–21.50	5.50–7.50	0.15–0.40	...	...
S24000	XM-29	0.08	11.50–14.50	0.060	0.030	1.00	17.00–19.00	2.25–3.75	0.20–0.40	...	...
S24565	...	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	0.4–0.6	4.0–5.0	Cb 0.10 max
S30200	302	0.15	2.00	0.045	0.030	1.00	17.00–19.00	8.00–10.00	0.10	...	...
S30400	304	0.08 [Note (3)]	2.00	0.045	0.030	1.00	18.00–20.00	8.00–10.50	0.10	...	...
S30403	304L	0.030	2.00	0.045	0.030	1.00	18.00–20.00	8.00–12.00	0.10	...	...
S30409	304H	0.04–0.10	2.00	0.040	0.030	1.00	18.00–20.00	8.00–10.50	...	...	...
S30451	304N	0.08	2.00	0.045	0.030	1.00	18.00–20.00	8.00–12.00	0.10–0.16	...	...
S30453	304LN	0.030	2.00	0.045	0.030	1.00	18.00–20.00	8.00–12.00	0.10–0.16	...	...
S30600	...	0.018 max	2.00	0.020	0.020	3.7–4.3	17.0–18.5	14.0–15.5	...	0.20	Cu 0.50 max
S30815	...	0.10	0.80	0.040	0.030	1.40–2.00	20.00–22.00	10.00–12.00	0.14–0.20	...	Ce 0.03–0.08
S30908	309S	0.08	2.00	0.045	0.030	1.00	22.00–24.00	12.00–15.00	...	...	...
S30909	309H	0.04–0.10	2.00	0.045	0.030	1.00	22.00–24.00	12.00–15.00	...	...	...
S30940	309Cb	0.08	2.00	0.045	0.030	1.00	22.00–24.00	12.00–16.00	0.10	...	(Cb+Ta) 10×C–1.10
S30880	ER308 [Note (4)]	0.08	1.00–2.50	0.030	0.030	0.25–0.60	19.50–22.00	9.00–11.00	...	...	...
S31008	310S	0.08	2.00	0.045	0.030	1.50	24.00–26.00	19.00–22.00	...	...	...
S31009	310H	0.04–0.10	2.00	0.045	0.030	1.50	24.00–26.00	19.00–22.00	...	...	...
S31040	310Cb	0.08	2.00	0.045	0.030	1.50	24.00–26.00	19.00–22.00	0.10	...	(Cb+Ta) 10×C–1.10
S31254	...	0.020	1.00	0.030	0.010	0.80	19.50–20.50	17.50–18.50	0.18–0.22	6.00–6.50	Cu 0.50–1.00
S31600	316	0.08 [Note (3)]	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	0.10	2.00–3.00	...
S31603	316L	0.030	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	0.10	2.00–3.00	...
S31609	316H	0.04–0.10	2.00	0.040	0.030	1.00	16.00–18.00	10.00–14.00	...	2.00–3.00	...
S31635	316Ti	0.08	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	0.10	2.00–3.00	Ti5×(C+N)–0.70
S31640	316Cb	0.08	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	0.10	2.00–3.00	(Cb+Ta) 10×C–1.10
S31651	316N	0.08	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	0.10–0.16	2.00–3.00	...
S31653	316LN	0.030	2.00	0.045	0.030	1.00	16.00–18.00	10.00–14.00	0.10–0.16	2.00–3.00	...

TABLE 1 (CONT'D)
CHEMICAL REQUIREMENTS

UNS Designation [Note (1)]	Type	Composition, %									
		Carbon, max [Note (2)]	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Chromium	Nickel	Nitrogen, max [Note (2)]	Molybdenum	Other Elements [Note (3)]
Austenitic Grades (Cont'd)											
S31700	317	0.08	2.00	0.045	0.030	1.00	18.00–20.00	11.00–15.00	0.10	3.00–4.00	...
S31725	...	0.03	2.00	0.045	0.030	1.00	18.00–20.00	13.50–17.50	0.10	4.0–5.0	Cu 0.75 max
S31726	...	0.03	2.00	0.045	0.030	1.00	17.00–20.00	13.50–17.50	0.10–0.20	4.0–5.0	Cu 0.75 max
S32100	321	0.08 [Note (5)]	2.00	0.045	0.030	1.00	17.00–19.00	9.00–12.00	...	...	Ti 5×(C+N)–0.70 [Note (6)]
S32109	321H	0.04–0.10	2.00	0.040	0.030	1.00	17.00–19.00	9.00–12.00	...	...	Ti4×(C+N)–0.70 [Note (6)]
S32615	...	0.07	2.00	0.045	0.030	4.80–6.00	16.50–19.50	19.00–22.00	...	0.30–1.50	Cu 1.50–2.50
S33228	...	0.04–0.08	1.00	0.020	0.015	0.30	26.00–28.00	31.00–33.00	...	...	Cb 0.60–1.00 Ce 0.05–0.10 Al 0.025 max
S34700	347	0.08 [Note (5)]	2.00	0.045	0.030	1.00	17.00–19.00	9.00–13.00	...	...	(Cb + Ta) 10×C min
S34709	347H	0.04–0.10	2.00	0.040	0.030	1.00	17.00–19.00	9.00–13.00	...	...	Cb 8×C–1.00
S34800	348	0.08 [Note (5)]	2.00	0.045	0.030	1.00	17.00–19.00	9.00–13.00	...	...	(Cb+Ta) 10×C min; Ta 0.01 max; Co 0.20 max
S34809	348H	0.04–0.10	2.00	0.040	0.030	1.00	17.00–19.00	9.00–13.00	...	...	Cb 8×C–1.00; Co 0.20 max
S35315	...	0.04–0.08	2.00	0.040	0.030	1.20–2.00	24.00–26.00	34.00–36.00	0.12–0.18	...	Ce 0.03–0.08
Austenitic-Ferritic Grades											
S31803	...	0.030	2.00	0.030	0.020	1.00	21.00–23.00	4.50–6.50	0.08–0.20	2.50–3.50	...
S32550	...	0.04	1.50	0.040	0.030	1.0	24.0–27.0	4.50–6.50	0.10–0.25	2.9–3.9	Cu 1.50–2.50
S32750	...	0.030	1.2	0.035	0.020	0.8	24.0–26.0	6.0–8.0	0.24–0.32	3.0–5.0	Cu 0.5 max
S32950	...	0.03	2.00	0.035	0.010	...	26.00–29.00	3.50–5.20	0.15–0.35	1.00–2.50	...
S39277	...	0.025	0.80	0.025	0.002	0.80	24.0–26.0	6.5–8.0	0.23–0.33	3.0–4.0	Cu 1.2–2.0 W 0.8–1.2
Ferritic Grades											
S40500	405	0.08	1.00	0.040	0.030	1.00	11.50–14.50	0.60 max	...	...	Al 0.10–0.30
S43000	430	0.12	1.00	0.040	0.030	1.00	16.00–18.00	...	...	...	...
S43035	439	0.07	1.00	0.040	0.030	1.00	17.00–19.00	0.50 max	0.04	...	Ti 0.20 + 4 × (C+N min
S44400	...	0.025	1.00	0.040	0.030	1.00	17.5–19.5	1.00 max	0.035	1.75–2.50	(Ti + Cb) 0.20 + 4 × (C+N)–0.80
S44627	XM-27	0.010 [Note (7)]	0.40	0.02	0.02	0.40	25.00–27.50	0.50 max	0.015 max [Note (7)]	0.75–1.50	Cu 0.20 max; Cb 0.05–0.20
S44700	...	0.010	0.30	0.025	0.020	0.20	28.00–30.00	0.15 max	0.020	3.50–4.20	(C+N) 0.025 max; Cu 0.15 max
S44800	...	0.010	0.30	0.025	0.020	0.20	28.00–30.00	2.00–2.50	0.020	3.50–4.20	(C+N) 0.025 max; Cu 0.15 max

TABLE 1 (CONT'D)
CHEMICAL REQUIREMENTS

UNS Designation [Note (1)]	Type	Composition, %									
		Carbon, max [Note (2)]	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Chromium	Nickel	Nitrogen, max [Note (2)]	Molybdenum	Other Elements [Note (3)]
Martensitic Grades											
S40300	403	0.15	1.00	0.040	0.030	0.50	11.50–13.00	...	...	...	...
S41000	410	0.15	1.00	0.040	0.030	1.00	11.50–13.50	...	...	...	...
S41040	XM-30	0.18	1.00	0.040	0.030	1.00	11.50–13.50	...	...	...	Cb 0.05–0.30
S41400	414	0.15	1.00	0.040	0.030	1.00	11.50–13.50	1.25–2.50	...	...	...
S41500	[Note (8)]	0.05	0.5–1.0	0.030	0.030	0.60	11.50–14.0	3.5–5.5	...	0.4–1.0	...
S43100	431	0.20	1.00	0.040	0.030	1.00	15.00–17.00	1.25–2.50	...	...	...

NOTES:
(1) New designations established in accordance with Practice E 527 and SAE J1086 published jointly by ASTM and SAE. See ASTM DS-56C.
(2) Maximum unless otherwise indicated.
(3) Except as required for specific alloy type, molybdenum, titanium, nickel, cobalt, tantalum, nitrogen, and copper need not be reported but shall not be present in other than residual amounts, the intent being to prohibit substitution of one alloy type for another due to absence of control of the above named elements in certain alloys.
(4) American Welding Society designation.
(5) See Supplementary Requirement S1.
(6) Nitrogen content is to be reported for this grade.
(7) Product analysis tolerance over the maximum limit for carbon and nitrogen to be 0.002%.
(8) Wrought version of CA6NM.

TABLE 2
MECHANICAL PROPERTY REQUIREMENTS

UNS Designation	Type	Condition	Tensile Strength, min, ksi [MPa]	Yield Strength, min. [Note (1)] ksi [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area min, % [Note (2)]	Brinell Hardness max
			Austenitic Grades				
S20161		annealed	125 [860]	50 [345]	40	40	255
S20910	XM-19	annealed	100 [690]	55 [380]	35	55	293
	Up to 2 in. (50.8 mm), incl	hot-rolled	135 [930]	105 [725]	20	50	...
	Over 2 to 3 in. (50.8 to 76.2 mm), incl	hot-rolled	115 [795]	75 [515]	25	50	...
	Over 3 to 8 in. (76.2 to 203.2 mm), incl	hot-rolled	100 [690]	60 [415]	30	50	...
	Up to ½ in. (38.1 mm), incl	strain-hardened	145 [1000]	125 [860]	12	40	...
	Over 1½ to 2¼ in. (38.1 to 57.2 mm), incl	strain-hardened	120 [825]	105 [725]	15	45	...
S21600, S21603	XM-17, XM-18	annealed	90 [620]	50 [345]	40	50	212
S21800	...	annealed	95 [655]	50 [345]	35	55	241
S21904	XM-11	annealed	90 [620]	50 [345]	45	60	...
S24000	XM-29	annealed	100 [690]	55 [380]	30	50	...
S24565	...	annealed	115 [795]	60 [415]	35	40	230
S30200, S30400, S30409, S30453, S30880, S30908, S30909, S31008, S31009, S31600, S31609, S31635, S31640, S31653, S31700, S32100, S32109, S34700, S34709, S34800, S34809, S30940, S31040	302, 304, 304H, 304LN, ER308, [Note (3)] 309S, 309H, 310S, 310H, 316, 316H, 316Ti, 316Cb, 316LN, 317, 321, 321H, 347, 347H, 348, 348H, 310Cb, 309Cb	annealed	75 [515] [Note (4)]	30 [205]	30	40	...
	316	strain-hardened level 1	85 [585]	65 [450] [Note (5)]	30	60	...
	2 in. and under	strain-hardened level 2	95 [655]	75 [515]	25	40	...
	Over 2 to 2½ in. (50.8 to 63.5 mm), incl	strain-hardened level 2	90 [620]	65 [450]	30	40	...
	Over 2½ to 3 in. (63.5 to 76.2 mm), incl	strain-hardened level 2	80 [550]	55 [380]	30	40	...
S30403, S31603	304L, 316L	annealed	70 [485]	25 [170]	30	40	...
S30451, S31651	304N, 316N	annealed	80 [550]	35 [240]	30	40	...
S30600	...	annealed	78 [540]	35 [240]	40	...	...
S30815	...	annealed	87 [600]	45 [310]	40	50	...
S31254	...	annealed	95 [655]	44 [305]	35	50	...
S31725	...	annealed	75 [515]	30 [205]	40	...	...
S31726	...	annealed	80 [550]	35 [240]	40	...	...
S32615	...	annealed	80 [550]	32 [220]	25	40	...
S33228	...	annealed	73 [500]	27 [185]	30	...	...
S35315	...	annealed	94 [650]	39 [270]	40	...	...

TABLE 2 (CONT'D)
MECHANICAL PROPERTY REQUIREMENTS

98

UNS Designation	Type	Condition	Tensile Strength, min, ksi [MPa]	Yield Strength, min. [Note (1)] ksi [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area min, % [Note (2)]	Brinell Hardness max
UNS Designation				**Austenitic-Ferritic Grades**			
S31803	...	annealed	90 [620]	65 [450]	25	...	290
S32550	...	annealed	110 [760]	80 [550]	15	...	297
S32750	2 in. and under	annealed	116 [800]	80 [550]	15	...	310
	over 2 in.	annealed	110 [760]	75 [515]	15	...	310
S32950	...	annealed	100 [690]	70 [485]	15	...	297
S39277	...	annealed	118 [820]	85 [585]	25	50	293
				Ferritic Grades			
S40500	405	annealed	60 [415]	25 [170]	20	45	207
S43000, S43035	430, 439	annealed	70 [485]	40 [275]	20 [Note (6)]	45 [Note (6)]	192
S44627	XM-27	annealed	65 [450]	40 [275]	...	45 [Note (6)]	217
S44400	...	annealed	60 [415]	45 [310]	20 [Note (7)]	45 [Note (7)]	217
S44700	...	annealed	70 [485]	55 [380]	20	40	...
S44800	...	annealed	70 [485]	55 [380]	20	40	...
				Martensitic Grades			
S40300, S41000	403, 410	annealed	70 [485]	40 [275]	20[D]	45[D]	223
		1	70 [485]	40 [275]	20 [Note (4)]	45 [Note (4)]	223
		2	110 [760]	85 [585]	15	45	269
		3	130 [895]	100 [690]	12	35	331
S41400	414	tempered	115 [795]	90 [620]	15	45	321
S41500	...	normalized and tempered	115 [795]	90 [620]	15	45	293
S43100	431 [Note (8)]	annealed	...	...	...	...	277
		tempered	115 [795]	90 [620]	15	45	321
S41040	XM-30	annealed	70 [485]	40 [275]	13 [Note (6)]	45 [Note (6)]	235
		quenched and tempered	125 [860]	100 [690]	13	45	302

NOTES:
(1) See Section 7.
(2) Reduction of area does not apply on flat bars $^{3}/_{16}$ in. [4.80 mm] and under in thickness as this determination is not generally made in this product size.
(3) American Welding Society designation.
(4) Tensile strength 70 ksi [485 MPa] min permitted for extruded shapes.
(5) For bars greater than 2 in. [51 mm], a cross section, 60 ksi [415 MPa] min, shall be permitted.
(6) Elongation in 2 in. or 50 mm of 12% min and reduction of area of 35% min permitted for cold-finished bars.
(7) Elongation in 2 in. of 12% min and reduction of area of 35% min permitted for cold-drawn or cold-rolled bars.
(8) Annealed bars shall be capable of meeting the tempered condition requirements when heat treated in accordance with 5.4.3.

TABLE 3
RESPONSE TO HEAT TREATMENT

Type [Note (1)]	Heat Treatment Temperature °F (°C), min [Note (2)]	Quenchant	Hardness HRC, min
403	1750 [955]	Air	35
410	1750 [955]	Air	35
414	1750 [955]	Oil	42

NOTES:
(1) Samples for testing shall be in the form of a section not exceeding $^{3}/_{8}$ in. [9.50 mm] in thickness.
(2) Temperature tolerance is +25°F [15°C].

SUPPLEMENTARY REQUIREMENTS

The following may be made requirements when the purchaser specifies them to be applicable.

S1. Materials for High-Temperature Service

S1.1 Unless an H grade has been ordered, this supplementary requirement shall be specified for ASME Code applications for service above 1000°F [540°C]. When invoked, all materials shall meet the requirements of the corresponding H grade including chemistry, annealing temperature, and grain size.

S2. Corrosion Tests

S2.1 Intergranular corrosion tests shall be performed by the manufacturer on sensitized specimens of Types 304L, 316L, 321, 347, and 348; and for the other austenitic grades, on specimens representative of the as-shipped condition. All austenitic stainless steels shall be capable of passing intergranular corrosion tests in the as-shipped condition. Tests shall be performed in accordance with Practice E of Practices A 262.

S3. Product Analysis

S3.1 An analysis shall be made by the manufacturer on a sample from one bar in each lot as defined in Specification A 484/A 484M. The analysis shall meet the requirements of Table 1. In the event of failure, the lot represented shall be rejected except that, at the option of the manufacturer, each bar in the lot may be tested for acceptance. Product analysis tolerance provisions do not apply.

S4. Material for High Cycle Fatigue Service

S4.1 The mechanical properties of bars furnished in lengths under 20 ft [6 m] shall be determined by testing one end of each bar. Bars furnished in lengths of 20 ft [6 m] and over shall be tested at each end.

S5. Material for Optimum Resistance to Stress Corrosion Cracking

S5.1 This supplementary requirement is to be referenced when austenitic stainless steels are to be purchased in accordance with 5.1.1 with solution-annealing as the final operation and with no subsequent cold drawing permitted. Straightening is permitted as a final operation to meet the straightness requirements of Specification A 484/A 484M unless specifically prohibited by the purchaser.

APPENDIX

(Nonmandatory Information)

X1. RATIONALE REGARDING DEFINITION OF SOLUTION ANNEALING IN 5.1.1

X1.1 It is generally recognized that austenitic stainless steels are solution annealed by heating to a temperature that dissolves (takes into solution) chromium carbides and quenching rapidly so that the chromium carbides will not participate in the grain boundaries which could cause susceptibility to intergranular corrosion in a critically corrosive environment. Thus, solution annealing also can be accomplished for non-stabilized grades by taking advantage of hot rolling temperatures (which always exceed solution annealing temperature requirements), maintaining hot rolling finishing temperatures well above minimum solution annealing requirements, and immediately quenching integral with hot rolling. Stabilized grades (with columbium or titanium added) cannot be handled this way since they would become destabilized due to columbium or titanium carbide solution, without subsequent reheating.

X1.2 For Boiler Code applications involving temperatures where optimum resistance to creep is desired, the larger grain size of material solution annealed by reheating is generally desired. For that reason a minimum grain size has been required of the H grades (created for optimum elevated temperature properties) and a mandatory grain size test and report has been added for the non-H grades so that the information is available for those desiring to reclassify a non-H grade to H grade.

X1.3 To satisfy the concerns of inadvertent assignment of fine grained material to elevated temperature applications, special marking has been added for material which meets the requirements of Supplementary Requirement S1.

X1.4 A mandatory test for susceptibility to intergranular corrosion has been added for material solution annealed by the alternative method [see (2) in 5.1.1] so that a history of data can be accumulated, as has been done in the past for material solution annealed by reheating.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, HIGH STRENGTH, FOR MODERATE AND LOWER TEMPERATURE SERVICE

SA-612/SA-612M

(Identical with ASTM Specification A 612/A 612M-90.) 98

1. Scope

1.1 This specification covers killed carbon-manganese-silicon steel plates intended for welded pressure vessels in service at moderate and lower temperatures.

1.2 The maximum thickness of plates supplied under this specification is 1 in. [25 mm].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and weight, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 Plates are normally supplied in the as-rolled condition. Plates may be ordered normalized or stress relieved, or both.

6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements* — The material as represented by the tension test specimens shall conform to the requirements shown in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

98

Elements	Composition, %	
	Thickness	
	0.750 in. [20 mm] and Under	Over 0.750 to 1 in. [20 to 25 mm], incl
Carbon, max:		
Heat analysis	0.25	0.25
Product analysis	0.29	0.29
Manganese		
Heat analysis	1.00–1.35	1.00–1.50
Product analysis	0.92–1.46	0.92–1.62
Phosphorus, max[A]	0.035	0.035
Sulfur, max[A]	0.035	0.035
Silicon		
Heat analysis	0.15–0.40	0.15–0.50
Product analysis	0.13–0.45	0.13–0.55
Copper, max:[B]		
Heat analysis	0.35	0.35
Product analysis	0.38	0.38
Nickel, max:[B]		
Heat analysis	0.25	0.25
Product analysis	0.28	0.28
Chromium, max:[B]		
Heat analysis	0.25	0.25
Product analysis	0.29	0.29
Molybdenum, max:[B]		
Heat analysis	0.08	0.08
Product analysis	0.09	0.09
Vanadium, max:[B]		
Heat analysis	0.08	0.08
Product analysis	0.09	0.09

[A] Applies to both heat and product analyses.
[B] When analysis shows that the amount of an element is 0.02% or lower, the value may be reported as ≦0.02%.

98

TABLE 2
TENSILE REQUIREMENTS

	Thickness	
	0.5 in. [12.5 mm] and Under	Over 0.5 in. to 1 in. [Over 12.5 to 25 mm]
Tensile strength, ksi [MPa]	83–105 [570–725]	81–101 [560–695]
Yield strength, min.[A] ksi [MPa]	50 [345]	50 [345]
Elongation in 8 in. [200 mm], min, %[B]	16	16
Elongation in 2 in. [50 mm], min, %	22	22

[A] Determined by either the 0.2% offset method or the 0.5% extension-under-load method.
[B] See Specification A 20/A 20M for elongation adjustments.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR STEEL, SHEET, CARBON, DRAWING QUALITY, SPECIAL KILLED, COLD-ROLLED

SA-620/SA-620M

(Identical with ASTM Specification A 620/A 620M-96 except for editorial changes in 6.1.1.) 98

1. Scope

1.1 This specification covers cold-rolled carbon steel sheet of drawing quality, special killed, in coils or cut lengths. This material is intended for fabricating identified parts where particularly severe drawing or forming may be involved or essential freedom from aging is required.

1.2 This specification is applicable for orders in either inch-pound units (as A 620) or SI units (as A 620M).

2. Referenced Documents

98 **2.1** *ASTM Standards:*

A 568/A 568M Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

A 619/A 619M Specification for Steel, Sheet, Carbon, Cold-Rolled, Drawing Quality

3. Terminology

3.1 *Definitions:*

3.1.1 *aging*—loss of ductility with an increase in hardness, yield point, and tensile strength that occur when steel, which has been slightly cold worked (such as by temper rolling), is stored for some time. Aging also increases the tendency toward stretcher strains and fluting.

3.1.2 *drawing quality special killed*—sheet manufactured from specially produced or selected killed steels (normally aluminum killed) specially processed to have good uniform drawing properties for use in fabricating an identified part having extremely severe deformations and to be essentially free from aging.

4. Classification

4.1 Cold-rolled sheet is supplied for either exposed or unexposed applications. Within the latter category, cold-rolled sheet is specified either “temper rolled” or “annealed last.” For details on processing, attributes and limitations, and inspection standards, refer to Specification A 568 or A 568M.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specifications A 568 or A 568M unless otherwise provided herein.

6. Ordering Information

6.1 Orders for material under this specification shall include the following information, as necessary, to describe adequately the required material:

6.1.1 Specification number and date of issue,

6.1.2 Name of material (cold-rolled sheet, drawing quality, special killed),

6.1.3 Class (either exposed, unexposed temper rolled, or annealed last) (see 4.1),

6.1.4 Finish (matte (dull) finish will be supplied on exposed, unless otherwise specified, and on unexposed) (see 10.1),

6.1.5 Oiling (material will be oiled unless ordered not oiled) (see 10.2),

6.1.6 Dimensions (decimal thickness, width, and length where applicable),

98 **6.1.6.1** As agreed upon between the purchaser and the producer, material ordered to this specification will be supplied to meet the appropriate standard or restricted thickness tolerance table shown in Specification A 568/A 568M.

NOTE 1 — Not all producers are capable of meeting all of the limitations of the thickness tolerance tables in Specification A 568/A 568M. The purchaser should contact the producer regarding possible limitations prior to placing an order.

6.1.7 Coil size and weight (include inside diameter, outside diameter, and maximum weight),

6.1.8 Quantity,

6.1.9 Application (show part identification and description),

6.1.10 Cast or heat (formerly ladle) analysis (if required) (see 12.1), and

6.1.11 Special requirements (if required).

NOTE 2 — A typical ordering description is as follows: "ASTM A 620 dated _____, exposed; cold-rolled, drawing quality, special-killed sheet; oiled; 0.035 by 53 in. by coil; ID 24 in.; OD 48 in., max; weight 15 000 lb, max; 100 000 lb; for instrument panel" or "ASTM A 620M dated _____, cold-rolled, drawing quality, special-killed sheet, exposed, oiled; 0.8 by 1340 mm by coil; ID 600 mm; OD 1500 mm, max; weight 10 000 kg, max; 45 000 kg; for instrument panel."

7. Manufacture

7.1 *Melting Practice*—The sheet shall be produced from special killed steel. It is normally produced from aluminum killed steel but may be otherwise deoxidized provided the material is capable of meeting the specified requirements.

8. Chemical Composition

8.1 The cast or heat analysis of the steel shall conform to the requirements prescribed in Table 1.

8.1.1 Unspecified elements may be present. Limits on elements shall be as stated in Table 2. 98

8.1.1.1 Each of the elements listed in Table 2 shall be included in the report of the heat analysis. When the amount of copper, nickel, chromium, or molybdenum is less than 0.02%, the analysis may be reported as <0.02%. When the amount of vanadium or columbium is less than 0.008%, the analysis may be reported as <0.008%. 98

9. Mechanical Properties

9.1 The sheet shall be suitable for the production of identified deep drawn parts. The manufacturer shall assume responsibility for selection of steel, control of processing, and ability of the material to form identified parts within properly established breakage limits. (Refer to Appendix X3 of Specifications A 568 or A 568M.)

9.2 Drawing quality, special killed steel is required when drawing quality (in accordance with Specification A619/A 619M) will not provide a sufficient degree of ductility for the fabrication of parts having stringent drawing requirements.

9.3 Refer to X4 of Specifications A 568 or A 568M for additional information.

9.4 For the purposes of pressure vessel design, the following minimum tensile properties may be assumed, 20 ksi yield strength and 40 ksi tensile strength.

10. Finish and Appearance

10.1 *Surface Finish:*

10.1.1 Unless otherwise specified, exposed sheet shall have a matte (dull) finish. When required, a controlled surface texture and condition may be specified.

10.1.2 Unexposed sheet shall have a matte (dull) finish. Surface texture or condition may not be specified.

10.2 *Oiling:*

10.2.1 Unless otherwise specified, the sheet shall be oiled.

10.2.2 When required, the sheet may be specified to be furnished not oiled (dry).

10.3 *Edges*—The sheet shall have cut edges.

98 11. Certification and Reports

11.1 While not normally required for this specification, upon request of the purchaser in the contract or order, a manufacturer's certification that the material was produced in accordance with this specification shall be furnished. The cast or heat analysis may be reported, if required.

98 12. Product Marking

12.1 In addition to the requirements of Specifications A 568 or A 568M, each lift or coil shall be marked with the designation, "DQSK."

98 13. Keywords

13.1 carbon steel sheet; cold rolled steel sheet; steel sheet

98

TABLE 1
CHEMICAL REQUIREMENTS[A]

Element	Composition, max, %
Carbon	0.10
Manganese	0.50
Phosphorus	0.020
Sulfur	0.030

[A] If aluminum is used as the deoxidizing agent, the aluminum content total by product analysis is usually in excess of 0.010%.

98

TABLE 2
LIMITS ON UNSPECIFIED ELEMENTS (SEE 8.1.1)

Copper, max %[A]	Heat analysis	0.20
	Product analysis	0.23
Nickel, max %[A]	Heat analysis	0.20
	Product analysis	0.23
Chromium, max %[A]	Heat analysis	0.15
	Product analysis	0.19
Molybdenum, max %[A]	Heat analysis	0.06
	Product analysis	0.07
Vanadium, max %	Heat analysis	0.008
	Product analysis	0.018
Columbium, max %	Heat analysis	0.008
	Product analysis	0.018

[A] The sum of copper, nickel, chromium, and molybdenum shall not exceed 0.50% on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining unspecified elements will apply.

SPECIFICATION FOR PRECIPITATION HARDENING IRON BASE SUPERALLOY BARS, FORGINGS, AND FORGING STOCK FOR HIGH-TEMPERATURE SERVICE

98

SA-638/SA-638M

(Identical with ASTM Specification A 638/A 638M-92.)

1. Scope

1.1 This specification covers hot-finished or cold-finished precipitation hardening iron base superalloy bars, forgings, and forging stock for high-temperature service. The mechanical properties of these alloys are developed by suitable solution treating and precipitation hardening treatments.

1.2 Two grades of iron base alloy are covered. Selection will depend upon design, service conditions, mechanical properties, and elevated temperature characteristics.

1.3 The values stated in either inch–pound units or SI (metric) units are to be regarded separately as standards; within the text and tables, the SI units are shown in [brackets]. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 Unless the order specifies an "M " designation, the material shall be furnished to inch–pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 484/A 484M Specification for General Requirements for Stainless and Heat-Resisting Bars, Billets and Forgings

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity (weight or number of pieces),

3.1.2 Name of material (precipitation hardening iron base superalloy),

3.1.3 Form (bars, forgings, and forging stock),

3.1.4 Dimensions (in the case of rough or finished forgings the order shall be accompanied by a print or drawing or otherwise adequately described as to the shape and dimension),

3.1.5 Grade designation (Table 1),

3.1.6 Condition (Section 5),

3.1.7 Finish (Section 3),

3.1.8 Mechanical requirements (Section 8),

3.1.9 ASTM designation, and

3.1.10 Special requirements.

4. General Requirements

4.1 In addition to the requirements of this specification, all requirements of the current edition of Specification A 484/A 484M shall apply. Failure to comply with the general requirements of Specification A 484/A 484M constitutes nonconformance with this specification.

5. Condition

5.1 The product forms covered in this specification may be furnished in one of the following conditions:

5.1.1 Hot-finished,

5.1.2 Solution treated (Grade 660 only — Type 1 or Type 2 solution treatment as specified),

5.1.3 Solution and precipitation treated (Grade 660 only — Type 1 or Type 2 solution treatment as specified), or

5.1.4 Other as specified.

6. Heat Treatment

6.1 Samples cut from bars, forgings, or a sample forged from the forging stock shall conform to the mechanical properties of Tables 3 and 4 when heat treated as prescribed in Table 2.

6.2 When a sample cut from the forging stock and heat treated as prescribed in Table 2 conforms to the properties in Tables 3 and 4, it shall be accepted as equivalent to a forged coupon.

7. Chemical Composition

7.1 The steel shall conform to the requirements for chemical composition specified in Table 1.

7.2 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751, except that for remelt material, product analysis tolerances may be used to determine conformance to this specification.

7.3 For referee purposes, Test Methods E 30 shall be used.

7.4 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Definitions A 751, except that for remelt material, product analysis tolerances may be used to determine conformance to this specification.

8. Mechanical Properties

8.1 The material shall conform to the mechanical property requirements specified in Table 3 after heat treatment as described in Table 2.

8.2 The material shall meet the requirements as to stress-rupture properties specified in Table 4 at the test temperature indicated after heat treatment as described in Table 2.

8.3 When specified in the ordering information (4.1.8), material may be ordered without stress-rupture testing. Material not stress-rupture tested shall be permanently stamped NR (See Section 10).

9. Metallurgical Properties

9.1 When specified, the grain size shall be 1 or finer.

10. Product Marking

10.1 Unless otherwise specified on the purchase order, each bundle shall be properly tagged with metal tags showing the purchase order number, heat number, name of alloy (or grade), *"NR" when material has not been stress-rupture tested,* specification number, and size.

10.1.1 Bars 1 in. [25 mm] in diameter, or 1 in. [25 mm] and over in thickness between parallel sides, shall be stamped with the heat number, and *if not stress-rupture tested, with the letters "NR"* within approximately 2 in. [50 mm] of one end. Smaller sizes shall be boxed or bundled and identified with metal tags as described in 10.1.

10.1.2 Forgings shall be identified as agreed upon between the seller and the purchaser.

11. Keywords

11.1 bars; forgings; forging stock; high temperature service; precipitation hardening iron base superalloy

TABLE 1
CHEMICAL REQUIREMENTS

	Grade 660 (UNS S66286)[A]		Grade 662 (UNS S66220)[A]	
	Ladle Analysis Range, %	Check Analysis Over or Under	Ladle Analysis Range, %	Check Analysis Over or Under
Carbon	0.08 max	0.01 over	0.08 max	0.01 over
Manganese	2.00 max	0.04 over	1.50 max	0.04
Silicon	1.00 max	0.05 over	1.00 max	0.05
Phosphorus	0.040 max	0.005 over	0.040 max	0.005 over
Sulfur	0.030 max	0.005 over	0.030 max	0.005 over
Chromium	13.50–16.00	0.20	12.00–15.00	0.15
Nickel	24.00–27.00	0.20	24.00–28.00	0.20
Molybdenum	1.00–1.50	0.05	2.50–3.50	0.10
Titanium	1.90–2.35	0.05	1.55–2.00	0.05
Copper	. . .	. . .	0.50 max	0.03 over
Aluminum	0.35 max	0.05 over	0.35 max	0.05 over
Vanadium	0.10–0.50	0.03	. . .	. . .
Boron	0.0010–0.010	0.004 under 0.001 over	0.0010–0.010	0.0004 under 0.001 over

[A] New designation established in accordance with Practice E 527 and SAE J1086.

TABLE 2
HEAT TREATMENT

Grade	Solution Treatment	Precipitation Hardening Treatment[A]
660	Type 1 1650 ± 25°F [900 ± 15°C], hold 2 hr, oil or water quench	1300 to 1400°F [705 to 760°C], hold 16 h, air cool or furnace cool
660	Type 2 1800 ± 25°F [980 ± 15°C], hold 1 h, oil or water quench	1300 to 1400°F [705 to 760°C], hold 16 h, air cool or furnace cool
662	1750 to 1900°F [955 to 1040°C] hold 1 h, min, oil or water quench	1250 to 1400°F [675 to 760°C], hold 5 h, min, slow cooling in 5 h, min to 1200 ± 15°F [650 ± 10°C], hold 20 h, min, air cool or furnace cool

[A] Times refer to the minimum time material is required to be at temperature.

TABLE 3
MECHANICAL PROPERTY REQUIREMENTS

	Grade 660	Grade 662 (bars)	Grade 662 (forgings)[B]
Heat treatment[A]	solution + precipitation harden	solution + precipitation harden	solution + precipitation harden
Tensile strength, min:			
psi	130 000	130 000	125 000
[MPa]	[895]	[895]	[860]
Yield strength (0.2% offset), min:			
psi	85 000	85 000	80 000
[MPa]	[585]	[585]	[550]
Elongation in 4D min, %	15	15	15
Reduction of area min, %	18	18	18
Brinell hardness	248 min	248 min	248 min

[A] Refer to Table 2 of heat treatment.
[B] The elongation of tensile specimens machined tangentially from near the center of large disk forgings over 50 in.^{2} [320 cm^2] in cross section may be as low as 10%. The reduction of area may be as low as 12%.

TABLE 4
STRESS-RUPTURE REQUIREMENTS

		Test Temperature		Stress			
Grade	Heat Treatment[A]	°F	[°C]	psi	[MPa]	Minimum Hours[B]	Minimum Elongation, %
660	solution + precipitation harden	1200	[650]	65 000	[450]	23	3
662	solution + precipitation harden	1200	[650]	60 000	[415]	15	3

[A] Refer to Table 2 for details of heat treatment.
[B] Test specimens meeting minimum requirements may be overloaded to produce rupture in a reasonable and practical time period.

SPECIFICATION FOR PRESSURE VESSEL PLATES, 5% NICKEL ALLOY STEEL, SPECIALLY HEAT TREATED

SA-645/SA-645M

(Identical with ASTM Specification A 645/A 645M-87.)

1. Scope

1.1 This specification covers austenitized, quenched, temperized, and reversion-annealed 5% nickel alloy steel plates intended primarily for welded pressure vessels for service at low or cryogenic temperatures.

1.2 The maximum thickness of plates which can be supplied under this specification is limited only by the capacity of the material to meet the specified requirements.

1.3 This material is susceptible to magnetization. Use of magnets in handling after heat treatment should be avoided if residual magnetism would be detrimental to subsequent fabrication or service.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Document

2.1 *ASTM Standard:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. Description of Terms Specific to This Standard

3.1 *Temperizing* — Heating to an optimum temperature and quenching to develop a microstructure containing some retained austenite and characterized by a lamellar pattern of alternate acicular grains of martensite and ferrite. This operation is performed subsequent to an initial austenitizing and quenching.

3.2 *Reversion Annealing* — Heating to an optimum temperature above the Ac_1, followed by quenching or air cooling to develop maximum toughness. This operation is performed subsequent to temperizing.

4. General Requirements and Ordering Information

4.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and weight, quality and repair of defects, marking, loading, etc.

4.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

4.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

4.3.1 Vacuum treatment,

4.3.2 Additional or special tension testing,

4.3.3 Impact testing, and

4.3.4 Nondestructive examination.

4.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

4.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

5. Manufacture

5.1 *Melting Process:*

5.1.1 The steel shall be made by an electric-furnace process.

5.2 *Steelmaking Practice* — The steel shall be killed.

6. Heat Treatment

6.1 All plates shall be heat treated in accordance with 6.2. Shell plates and other parts, including heads and reinforcing pads, which are heated above 1125°F [605°C] for forming, shall be heat treated after forming,

6.2 *Procedure and Sequence:*

6.2.1 *Hardening:*

6.2.1.1 The plates shall be heated to a temperature of 1575 to 1675°F [855 to 915°C], held at this temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and then water-quenched to below 300°F [150°C].

6.2.2 *Temperizing:*

6.2.2.1 The plates shall be reheated to a temperature of 1275 to 1400°F [690 to 760°C], held at this temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and then water-quenched to below 300°F [150°C].

6.2.3. *Reversion Annealing:*

6.2.3.1 The plates shall be reheated to a temperature of 1150 to 1225°F [620 to 665°C], held at this temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and then water-quenched or air cooled to below 300°F [150°C].

7. Chemical Requirements

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

8. Mechanical Requirements

8.1 *Tension Tests* — The material as represented by tension test specimens shall conform to the requirements prescribed in Table 2.

8.1.1 For nominal plate thicknesses of $\frac{3}{4}$ in. [20 mm] and under, the $1\frac{1}{2}$ in. [40 mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation.

8.2 *Impact Tests:*

8.2.1 Charpy V-notch tests shall be made in accordance with the general requirements of Specification A 20/A 20M.

8.2.2 The longitudinal axis of the test specimens shall be transverse to the final direction of rolling of the plate.

8.2.3 Unless otherwise agreed, tests shall be conducted at −275°F [−170°C].

8.2.4 Each specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

8.2.5 The values of energy absorption in foot-pounds-force [joules] and the fracture appearance in percent shear shall be recorded and reported for information.

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %	
Element	Heat Analysis	Product Analysis
Carbon, max	0.13	0.15
Manganese	0.30–0.60	0.25–0.66
Phosphorus, max	0.025	0.035
Sulfur, max	0.025	0.035
Silicon	0.20–0.40	0.18–0.45
Nickel	4.75–5.25	4.65–5.35
Molybdenum	0.20–0.35	0.17–0.38
Aluminum, total	0.02–0.12	0.01–0.16
Nitrogen, max	0.020	0.025

TABLE 2
TENSILE REQUIREMENTS

	ksi [MPa]
Yield strength, min[A]	65 [450]
Tensile strength	95–115 [655 to 795]
Elongation in 2 in. [50 mm], min, %[B]	20.0

[A] At 0.2% offset. Upon agreement between the purchaser and the manufacturer, yield strength may be determined by the total extension-under-load method, using a total extension of 0.005 in./in. [0.005 mm/mm].
[B] See Specifiction A 20/A 20M.

TABLE 3
CHARPY IMPACT REQUIREMENTS FOR LONGITUDINAL SPECIMENS

Size of Specimen, mm	Charpy V-notch Impact Value Required for Acceptance (Average of Three Specimens), ft·lbf [J]	Minimum Charpy V-notch Impact Value Without Requiring Retest (One Specimen Only of a Set), ft·lbf [J]
10 by 10	25 [34]	20 [27]
10 by 7.5	19 [26]	16 [22]
10 by 6.67	17 [23]	13 [18]
10 by 5.0	13 [18]	10 [14]
10 by 3.33	8 [11]	7 [10]
10 by 2.50	6 [8]	5 [7]

TABLE 4
CHARPY IMPACT REQUIREMENTS FOR TRANSVERSE SPECIMENS

Size of Specimen, mm	Charpy V-notch Impact Value Required for Acceptance (Average of Three Specimens), ft·lbf [J]	Minimum Charpy V-notch Impact Value Without Requiring Retest (One Specimen Only of a Set), ft·lbf [J]
10 by 10	20 [27]	16 [22]
10 by 7.5	15 [20]	12 [16]
10 by 6.6	13 [18]	10 [14]
10 by 5.0	10 [14]	8 [11]
10 by 3.33	7 [10]	5 [7]
10 by 2.50	5 [7]	4 [5]

SUPPLEMENTARY REQUIREMENTS

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Supplementary requirements shall not apply unless specified in the order. Those which are considered suitable for use with this specification are listed below by title. Others enumerated in Specification A 20/A 20M may be used with this specification subject to agreement by the supplier.

S1. Vacuum Treatment,

S2. Product Analysis,

S6. Drop-Weight Tests,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDED SUPPLEMENTARY REQUIREMENTS

Also listed below are additional supplementary requirements which are considered suitable for use with this specification.

S64. Longitudinal Charpy Impact Energy Absorption Requirement

S64.1 When required, the purchaser may specify longitudinal Charpy V-notch impact testing to energy-absorption acceptance criteria.

S64.2 Tests shall be conducted in accordance with the general requirements of Specification 20/A 20M.

S64.3 The longitudinal Charpy V-notch impact properties shall not be less than those shown in Table 3.

S64.4 The impact values obtained on subsize specimens shall not be less than the values listed in Table 3.

S65. Transverse Charpy Impact Energy Absorption Requirement

S65.1 When required, the purchaser may specify transverse Charpy V-notch impact testing to energy-absorption acceptance criteria.

S65.2 Tests shall be conducted in accordance with the general requirements of Specification A 20/A 20M.

S65.3 The transverse Charpy V-notch impact properties shall not be less than those shown in Table 4.

S65.4 The impact values obtained on subsize specimens shall not be less than the values listed in Table 4.

SPECIFICATION FOR FORGED STEEL ROLLS USED FOR CORRUGATING

SA-649/SA-649M

(Identical with ASTM Specification A 649/A 649M-94a.)

1. Scope

1.1 This specification covers two kinds of rolls used in machinery for producing corrugated paperboard. Rolls are fabricated of forged bodies and trunnions. The trunnions may be bolted or shrink assembled on one or both ends of the body. A seal weld may be made at the body/trunnion interface. Roll shells are made of carbon/manganese, or low alloy steel as hereinafter described, and are heat treated prior to assembly. Pressure rolls are surface hardened. Provision is made in supplementary requirement S1 for the optional surface hardening of corrugating rolls.

1.2 Corrugating and pressure rolls made to this specification shall not exceed 18 in. [455 mm] in inside diameter. The wall thickness of the roll body shall not be less than 1/12 of the inside diameter or 1 in. [25 mm], whichever is greater, but shall not exceed 3 in. [75 mm]. The wall thickness of the corrugating roll is measured at the bottom of the corrugations in the location of the trunnion fit. The maximum operating temperature of the roll is 425°F [225°C] and the maximum allowable working pressure is 250 psi [1.70 MPa]. The minimum design temperature shall be 40°F [4°C]. The maximum stresses on the roll bodies and the trunnions from the combined internal and external loading are limited to 15 000 psi [103.4 MPa] for the trunnions, 18 750 psi [129 MPa] for the Class 2 pressure roll bodies, and 20 000 psi [138 MPa] for Class 1A, 1B, or 5 pressure roll or corrugating roll bodies in Grade 1 or 2.

1.3 Referring to Table 1, material to Classes 1 A, 1 B, or 5 shall be used for the manufacture of corrugating or pressure roll shells, and Class 2 shall be used only for pressure roll shells. Trunnions shall be made from forgings in either Class 3 or Class 4.

1.4 The values stated in either inch-pound units or SI [metric] units are to be regarded separately as standards. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

1.6 Except as specifically required in this standard, all of the provisions of Specification A 788 apply.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 788 Specification for Steel Forgings, General Requirements

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron Open-Hearth Iron, and Wrought Iron

3. Ordering Information

3.1 Orders for material under this specification shall include the information required by Specification A

788. The purchaser should refer to Specification A 788 for other relevant information.

3.2 The additional ordering information given in Specification A 788 shall be specified as necessary to describe adequately the desired material.

4. Materials and Manufacture

4. 1 *Forging Process:*

4.1.1 Roll body forgings may be made as solid forgings and subsequently bored.

4.1.2 Trunnions or gudgeons which are to be subsequently assembled to form the roll shall be made as a solid forging or where practical upset from segments cut from billets or bars.

4.2 *Heat Treatment:*

4.2.1 *Heat Treatment for Mechanical Properties (Requirements do not apply to surface treatment.):*

4.2.1.1 *Machining* — The forged roll body shall have all surfaces rough machined, including boring, prior to heat treatment for mechanical properties.

4.2.1.2 Roll bodies shall be normalized, liquid quenched, and tempered to produce the required mechanical properties, except that for Class 2 forgings, and when Grade 2 strength requirements are specified, a normalize and temper heat treatment may be applied.

4.2.1.3 The trunnions shall be normalized and tempered or annealed to produce the required mechanical properties.

4.2.2 *Surface Hardening of Pressure Roll Forgings* — The working face of pressure rolls shall be surface hardened either before or after fitting the trunnions, at the manufacturer's option.

4.3 *Assembly and Weld* — Except for integrally forged or bolted-on trunnions, the assembly shall be made by shrink fitting trunnions into the prepared body ends. If used, welding of the trunnion to the roll body is restricted to a $\frac{3}{8}$ in. (9.5 mm) max. seal weld, made with low hydrogen materials. A minimum preheat of 400°F (205°C) and a minimum postweld heat treatment of 850°F (455°C) for 8 h shall be used. The maximum post weld heat treatment shall be not higher than $t - 50$°F ($t - 28$°C) where t is the final tempering temperature. All welds shall be machined or ground for the final magnetic particle examination.

5. Chemical Composition

5.1 The steel shall conform to the requirements for chemical composition prescribed in Table 1.

5.2 *Method of Analysis* — Test Methods E 30 shall be used for referee purposes.

6. Mechanical Properties

6.1 *Tensile Requirements:*

6.1.1 The material shall conform to the requirements for tensile properties prescribed in Table 2 when tested in accordance with Test Methods and Definitions A 370. Tension test specimens shall be the standard round $\frac{1}{2}$ in. [12.5 mm] diameter, 2 in. [50 mm] gage length. The yield strength prescribed in Table 2 shall be determined by the 0.2% offset method.

6.1.1.1 Tests for acceptance shall be made after the heat treatment of the forgings, for mechanical properties in accordance with 4.2.1.

6.1.2 *Number, Location, and Orientation of Test Specimens:*

6.1.2.1 *Roll Body Forgings* — A full-size prolongation shall be provided on a roll body forging representing each heat of steel in each heat-treatment furnace charge. One longitudinal tension test specimen shall be taken from the prolongation and the axis of the specimen shall be located midway between the inner and outer surfaces of the wall body.

6.1.2.2 *Trunnions* — Test material shall be provided from each heat of steel in each heat-treatment furnace charge. One longitudinal tension specimen shall be taken from each test piece and the axis of the specimen shall be located at any point midway between the center and surface of the solid forging.

6.2 *Hardness:*

6.2.1 Roll body forgings shall have a Brinell hardness from 352 HB to 415 HB (Grade 1) or 207 HB to 285 HB (Grade 2). No less than three hardness determinations shall be made on each roll. The hardness readings are to be taken on the outside of the roll bodies using care to prepare locations for tests that are free of decarburization but not so deep as to affect the usefulness of the material.

6.2.2 The surface hardened pressure roll body forgings shall have a hardness of 58 HRC to 65 HRC or equivalent. No less than three hardness determinations shall be made on each roll. The hardness depth shall not exceed $\frac{1}{4}$ [6 mm].

7. Retreatment

7.1 If the results of the mechanical tests of any forging do not conform to the specified requirements, the manufacturer may retreat the forging one or more times, but not more than three additional times without approval of the purchaser.

8. Magnetic Particle Examination

8.1 The entire surface of the roll including the seal weld area shall be examined by a wet continuous method in accordance with Test Method A 275/A 275M after machining or grinding. The use of prods is not permitted.

8.2 Only indications with major dimensions greater than $\frac{1}{8}$ in [3.2 mm] are considered relevant.

8.3 *Acceptance Standards* — The following relevant indications are unacceptable:

8.3.1 Any linear indications greater than $\frac{3}{16}$ in. [4.8 mm] long.

8.3.2 Rounded indications greater than $\frac{3}{16}$ in. [4.8 mm].

8.3.3 Four or more indications in a line separated by $\frac{1}{16}$ in. [1.6 mm] or less edge to edge.

8.3.4 Ten or more indications in any 6 in.^{2} [38.71 cm^2] of surface.

9. Hydrostatic Testing

9.1 The machined roll assembly shall be hydrostatic tested at $1\frac{1}{2}$ times the maximum operating pressure. The operating pressure shall be furnished by the purchaser.

9.2 The recommended minimum hydrostatic test temperature is 70°F [21°C].

10. Package Marking, Packaging, and Loading

10.1 Packaging and loading shall be done so the forging is not damaged during shipment to the purchaser.

11. Keywords

11.1 internal pressure; machinery — corrugating; roll assembly — forged; rolls — corrugating; rolls — pressure; steel forgings — alloy; steel forgings — carbon; steel rolls; surface-hardened; trunnions — shrink-fitted

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %					
	Class 1A	Class 1B	Class 2	Class 3	Class 4	Class 5
Carbon	0.45–0.60	0.40–0.60	0.55 max	0.35 max	0.35 max	0.50–0.60
Manganese	0.55–1.05	0.60–0.95	0.50–0.90	0.40–0.70	0.60–1.05	0.90–1.50
Phosphorus	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max
Sulfur	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max
Silicon [Note (1)]	0.15–0.35	0.15–0.35	0.15–0.35 max	0.15–0.35	0.15–0.35 max	0.15–0.35
Nickel	. . .	1.55–2.00	. . .	. . .	. . .	0.60 max
Chromium	0.80–1.15	0.65–0.93	. . .	0.80–1.15	. . .	0.30 max
Molybdenum	0.15–0.50	0.20–0.30	. . .	0.15–0.25	. . .	0.15 max

NOTE:
(1) When vacuum carbon deoxidation (VCD) is used the silicon content shall be 0.010% maximum.

TABLE 2
TENSILE REQUIREMENTS

Class	Grade	Yield Strength, min [Note (1)]		Tensile Strength, min		Elongation in 2 in. or 50 min, %	Reduction of Area, %
		ksi	[MPa]	ksi	[MPa]		
1A, 1B or 5	1	130	[890]	150	[1030]	12.0	30
1A, 1B or 5	2	65	[450]	100	[690]	14.0	30
2	. . .	37.5	[260]	75	[515]	20.0	50.0
3 or 4	. . .	30	[205]	60	[415]	22.0	55

NOTE:
(1) 0.2% offset.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser on the order and agreed to by the manufacturer.

S1. Surface-Hardened Corrugating Rolls

S1.1 After all surfaces have been machined, the outer surface of the corrugating rolls may be surface-hardened to a surface hardness of Rockwell 53 HRC to 65 HRC. The depth of hardness shall not exceed $\frac{3}{8}$ in. [9.5 mm]. A minimum of three hardness determinations shall be made on the surface. Additional hardness tests shall be made to establish the depth of hardness. The hardened surface shall be magnetic particle tested (see Section 8).

S2. Notch Toughness

S2.1 For applications where minimum notch toughness limits are required, impact testing shall be specified for both roll bodies and trunnions. The following requirements shall be specified:

S2.1.1 Type of impact specimen and test standard (for example, ASTM A 370 specimen Type A or B).

S2.1.2 Minimum value for absorbed energy or lateral expansion.

S2.1.3 Test temperature.

S2.1.4 Frequency of testing.

S2.2 Trunnion and pressure rolls may be liquid quenched and tempered instead of the heat treatments specified in 4.2 when impact testing is required.

SPECIFICATION FOR CENTRIFUGALLY CAST CARBON STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

SA-660

(Identical to ASTM Specification A 660-91a.) 98

1. Scope

1.1 This specification covers carbon steel pipe made by the centrifugal casting process intended for use in high-temperature, high-pressure service. Pipe ordered under this specification shall be suitable for fusion welding, bending, and other forming operations.

1.2 Several grades of carbon steels are covered. Their compositions are given in Table 1.

1.3 Supplementary requirements (S1 to S9) of an optional nature are provided. The supplementary requirements call for additional tests to be made, and when desired shall be so stated in the order, together with the number of such tests required.

1.4 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 94 Guide for Radiographic Testing

E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Testing by the Contact Method

E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings

E 142 Method for Controlling Quality of Radiographic Testing

E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (51 to 114-mm) Steel Castings

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms; and Forgings

E 446 Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness

2.2 *ANSI Standards:*

B36.10 American Standard for Welded and Seamless Wrought Steel Pipe

B46.1 Surface Texture

2.3 *MSS Standards:*

SP-54 Quality Standard for Steel Castings—Radiographic Inspection Method

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following as required, to describe the desired material adequately:

4.1.1 Quantity (feet, meters, or number of lengths),

4.1.2 Name of material (centrifugally cast pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (outside or inside diameter and minimum wall thickness),

4.1.5 Length (specific or random), (Permissible Variations in Length Section of Specification A 530/A 530M),

4.1.6 End Finish (Ends Section of Specification A 530/A 530M),

4.1.7 Optional Requirements (Sections 7.2, 8.2, 8.3, 11.1, Section 12 and S1 to S9 Supplementary Requirements),

4.1.8 Test report required (Certification Section of Specification A 530/A 530M),

4.1.9 Specification designation, and

4.1.10 Special requirements.

5. Materials and Manufacture

5.1 *Machining:*

5.1.1 All centrifugally cast pipe shall have both the inner and outer surfaces machined.

5.1.2 After heat treatment, the pipe shall be machined to a finish with a roughness value no greater than 250 μin. (6.35 μm) arithmetical average deviation (AA), terms as defined in ANSI B46.1 unless otherwise specified.

5.2 *Heat Treatment:*

5.2.1 All pipe shall receive a heat treatment proper for its design and chemical composition.

5.2.2 Castings shall be heat treated after they have been allowed to cool below the transformation range.

6. Temperature Control

6.1 Furnace temperatures for heat treating shall be effectively controlled by pyrometers.

7. Chemical Requirements

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7.2 *Product Analysis:*

7.2.1 At the request of the purchaser, a product analysis shall be made by the manufacturer on every heat.

7.2.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Table 1.

7.2.3 If the analysis of one of the tests specified in 7.2.1 does not conform to the requirements specified, an analysis of each pipe from the same heat may be made, and all pipes conforming to the requirements shall be accepted.

8. Mechanical Requirements

8.1 *Tensile Properties:*

8.1.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2. **98**

8.1.2 *Transverse or Longitudinal Tension Test* — One test shall be made on a specimen from one end of one length of pipe representing each heat in each heat-treatment lot.

8.2 *Flattening Test:*

8.2.1 A flattening test shall be performed when requested by the purchaser or when stated by the purchaser on the order that the pipe is to be upset, swaged, expanded, bent, or formed by some other operation.

8.2.2 A flattening test need not be performed on heavy wall pipe which is not to be upset, swaged, expanded, bent, or formed in some other manner.

8.2.3 When required by 8.2, a test shall be made on specimens cut from one end of each length of pipe.

8.2.4 A flattening test when required shall be performed in accordance with the requirements for seamless and centrifugally cast pipe in the Flattening Test Requirements Section of Specification A 530/A 530 M.

NOTE 2—In heavy-walled small-diameter tubing the flattening test specimen may be bored out so that the *OD/t* ratio will be greater than 11.0.

8.3 *Hydrostatic Test:*

8.3.1 Each length of pipe shall be hydrostatically tested in accordance with the Hydrostatic Test Requirements Section of Specification A 530/A 530M when requested by the purchaser and stated on the order. If performance of the hydrostatic test is not required by the purchaser, the manufacturer shall guarantee pipe to pass the test and mark each length of pipe with the letters “NH” immediately following the specification

number, indicating that the pipe has not been hydrostatically tested.

8.3.2 When required by 8.3, each length of pipe shall be subjected to the hydrostatic test. The test pressure shall be maintained for not less than 5 min.

9. Permissible Variation in Wall Thickness

9.1 The wall thickness shall not vary over the specified minimum wall thickness by more than 10%. There shall be no variation under the specified minimum wall thickness.

NOTE 3—A system of standard pipe sizes has been approved by the American National Standards Institute, as ANSI B36.10. This system may be used for obtaining pipe under this specification.

10. Workmanship and Finish

10.1 The pipe shall have a finish as provided in 5.2 and it shall be reasonably straight and free from injurious defects.

11. Rework and Retreatment

11.1 *Imperfections* — The surface of the casting shall be inspected visually for cracks and hot tears. These imperfections shall be removed, and their removal verified by visual inspection of the resultant cavities. Imperfections located by inspecting with Supplementary Requirements S7, S8, or S9 shall be removed or reduced to an acceptable size.

11.2 *Blending* — If removal of the imperfection does not infringe upon the minimum wall thickness, the depression may be blended uniformly into the surrounding surface.

11.3 *Repair by Welding* — Imperfections that infringe upon the minimum wall thickness may be repaired by welding subject to approval by the purchaser. Only qualified operators and procedures in accordance with ASME Boiler and Pressure Vessel Code, Section IX, shall be used. All weld repairs shall be inspected to the same quality standards used to inspect the pipe.

11.4 *Reheat Treatment* — Local or full heat treatment in accordance with 5.2 shall follow welding. Local grinding following welding and retreating shall be considered as meeting the requirements of 5.1.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include the wall thickness, piece mark, length and additional symbol “S” if the pipe conforms to one or more of the supplementary requirements specified in S1 to S9, and the heat number or manufacturer’s number by which the heat can be identified. Identification stamping instead of stenciling will be permitted only with the written approval of the purchaser.

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, max, %		
	Grade WCA	Grade WCB	Grade WCC
Carbon	0.25[A]	0.30	0.25[B]
Manganese	0.70[A]	1.00	1.20[B]
Phosphorus	0.035	0.035	0.035
Sulfur	0.035	0.035	0.035
Silicon	0.60	0.60	0.60

[A] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% mangangese above the specified maximum will be permitted up to a maximum of 1.10%.

[B] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted to a maximum of 1.40%.

TABLE 2
TENSILE REQUIREMENTS

	WCA		WCB		WCC	
	ksi	MPa	ksi	MPa	ksi	MPa
Tensile strength, min	60	414	70	483	70	483
Yield Strength, min	30	207	36	248	40	276
Elongation in 2 in. or 50 mm, min, %	24		22		22	
Reduction of area, min, %	35		35		35	

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Additional Tension Tests

S2.1 An additional tension test shall be made on a specimen from one or each end of each pipe. If this supplementary requirement is specified, the number of tests per pipe required shall be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest.

S3. Additional Flattening Tests

S3.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Metal Structure and Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Photomicrographs

S5.1 The manufacturer shall furnish one photomicrograph at 100 diameters from a specimen of pipe in the as-finished condition representing each heat in each heat-treatment lot. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S6. Such photomicrographs are for information only, to show the actual metal structure of the pipe as furnished.

S6. Photographs for Individual Pieces

S6.1 In addition to the photomicrographs required in accordance with Supplementary Requirement S5, the purchaser may specify that photomicrographs shall be furnished from one or both ends of each pipe. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S7. Radiographic Inspection

S7.1 The pipe shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with Practice E 94

or Method E 142 and the types and severity levels of discontinuities considered shall be judged by Reference Radiographs E 446, or Reference Radiographs E 186. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser. A specification which may be used as a basis for such agreement is "Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components (Radiographic Inspection Method SP-54)" of the Manufacturer's Standardization Society of the Valve and Fittings Industry.

S8. Ultrasonic Tests

S8.1 Each pipe shall be ultrasonically tested to determine its soundness throughout the entire length of the pipe. Evidence of the existence of defects in excess of 5% of the wall thickness shall be cause for rejection or repair.

S8.2 The ultrasonic test shall be made in accordance with Practice E 114, or by any other established method mutually agreed upon between the manufacturer and the purchaser.

S9. Magnetic Particle or Fluid Penetrant Examination

S9.1 Each pipe along outside and inside surfaces shall be subjected, after machining, to examination by a magnetic particle method or a penetrant fluid and powder method.

S9.2 The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser. Reference Photographs E 125 may be used to define acceptance criteria.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON-MANGANESE, FOR MODERATE AND LOWER TEMPERATURE SERVICE

SA-662/SA-662M

(Identical with ASTM Specification A 662/A 662M-93.) 98

1. Scope

1.1 This specification covers carbon-manganese steel plates intended primarily for service in welded pressure vessels where improved low temperature notch toughness is important.

1.2 Material under this specification is available in three grades as follows:

Grade	Tensile Strength, ksi [MPa]
A	58–78 [400–540]
B	65–85 [450–585]
C	70–90 [485–620]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements: however, current practice normally limits the maximum thickness of plates furnished under this specification to 2 in. [50 mm].

1.4 Grades A, B, and C comply substantially with the requirements of ISO Pressure Vessel Steels P9, P15, and P18, respectively.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents: therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality, and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification certain supplementary requirements are available when additional control, testing, or examination is required to meet the end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.4.1 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates of Grade A and plates of Grades B and C over $1\frac{1}{2}$ in. [40 mm] in thickness shall be normalized.

5.2 Plates of Grades B and C, $1\frac{1}{2}$ in. [40 mm] and under in thickness, are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The material as represented by the tension test specimen shall conform to the requirements prescribed in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

98

	Composition, %					
	Grade A		Grade B		Grade C	
Element	Heat Analysis	Product Analysis	Heat Analysis	Product Analysis	Heat Analysis	Product Analysis
Carbon, max	0.14	0.17	0.19	0.22	0.20	0.24
Manganese	0.90–1.35	0.84–1.46	0.85–1.50	0.79–1.62	1.00–1.60	0.92–1.72
Phosphorus, max	0.035	0.035	0.035	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035	0.035	0.035	0.035
Silicon	0.15–0.40	0.13–0.45	0.15–0.40	0.13–0.45	0.15–0.50	0.13–0.55

TABLE 2
TENSILE PROPERTIES

98

	Grade A	Grade B	Grade C
Tensile strength, ksi [MPa]	58–78 [400–500]	65–85 [450–585]	70–90 [485–620]
Yield strength,[A] min, ksi [MPa]	40 [275]	40 [275]	43 [295]
Elongation in 8 in. [200 mm], min, %[B]	20	20	18
Elongation in 2 in. [50 mm], min, %	23	23	22

[A] Determined by either the 0.2% offset method of the 0.5% extension-under-load method.
[B] See Specification A 20/A 20M for elongation adjustments.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified on the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test (see Appendix X1),

S6. Drop Weight Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

APPENDIX

(Nonmandatory Information)

X1. NOTCH TOUGHNESS

X1.1 When Charpy V-notch testing is required, the minimum values listed Table X1.1 will be guaranteed on normalized material for the temperature specified by the purchaser.

TABLE X1.1
CHARPY V-NOTCH REQUIREMENTS[A]

	Grade A		Grades B and C	
Testing Temperature, °F [°C]	Longitudinal Specimens, ft·lbf [J]	Transverse Specimens, ft·lbf [J]	Longitudinal Specimens, ft·lbf [J]	Transverse Specimens, ft·lbf [J]
−75 [−60]	20 [27]	15 [20]	15 [20]	. . .
−60 [−50]	30 [41]	18 [24]	20 [27]	. . .
−50 [−45]	35 [47]	19 [26]	22 [30]	15 [20]
−40 [−40]	40 [54]	20 [27]	25 [34]	20 [27]
−25 [−32]	45 [61]	25 [34]	30 [41]	20 [27]
0 [18]	55 [75]	30 [41]	35 [47]	25 [34]
32 [0]	70 [95]	35 [47]	40 [54]	25 [34]
75 [25]	75 [102]	40 [54]	50 [68]	30 [41]

[A] The above values apply to the average of three full size specimens. Values for subsize specimens are denoted as listed in Specification A 20/A 20M.

SPECIFICATION FOR AUSTENITIC STAINLESS STEEL, SHEET, STRIP, PLATE, AND FLAT BAR

SA-666

(Identical with ASTM Specification A 666-96)

1. Scope

1.1 This specification covers austenitic stainless steels in the annealed and normally required cold-worked conditions for various structural, architectural, pressure vessel, magnetic, cryogenic, and heat-resisting applications. (This revision of Specification A 666 replaces prior Specifications A 412 and A 177).

1.2 The application of this specification, or the use of material covered by this specification does not automatically allow usage in pressure vessel applications. Only annealed conditions of grades specifically approved by the ASME code are permitted for pressure vessel use.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards*

A 240/A 240M Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 484/A 484M Specification for General Requirements for Stainless and Heat Resisting Steel Bars, Billets, and Forgings

3. General Requirements

3.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 480/A 480M or A 484/A 484M:

3.1.1 Definitions,

3.1.2 General requirements for delivery,

3.1.3 Ordering information,

3.1.4 Process,

3.1.5 Special tests,

3.1.6 Heat treatment,

3.1.7 Dimensions and permissible variations,

3.1.8 Workmanship, finish and appearance,

3.1.9 Number of tests/test methods,

3.1.10 Specimen preparation,

3.1.11 Retreatment,

3.1.12 Inspection,

3.1.13 Rejection and rehearing,

3.1.14 Material test report,

3.1.15 Certification, and

3.1.16 Packaging, marking, and loading.

4. Chemical Composition

4.1 The steel shall conform to the requirements as to chemical composition specified in Table 1, and shall

conform to applicable requirements specified in the current edition of Specification A 480/A 480M.

5. Mechanical Properties

5.1 The material shall conform to the mechanical properties specified in Tables 2 and 3, or Table 4.

6. Sampling

6.1 Tension and bend-test specimens of sheet, strip, and plate products shall be selected from finished material and shall be selected in the transverse direction, except in the case of strip under 9 in. (229 mm) in width, in which case tension test specimens shall be selected in the longitudinal direction.

6.2 Flat bar tension and bend-test specimens shall be selected from the finished material and shall be in the longitudinal direction.

6.3 Corrosion samples, if required, shall be taken from material after final annealing and descaling and prior to cold working.

7. Number of Tests

7.1 For flat bar products at least one tension test and one bend test shall be made on each size from each heat in a lot annealed in a single charge or under the same conditions in a continuous furnace.

8. Test Methods

8.1 *Tension Test:*

8.1.1 The yield strength shall be determined by the offset method as described in Test Methods and Definitions A 370. An alternative method of determining field strength may be used based on the following total extension under load:

Yield Strength, min, psi	Total Extension under Load in 2 in. Gage Length, incl.
45 000	0.0071
75 000	0.0098
110 000	0.0125
135 000	0.0144
140 000	0.0148

8.1.2 The requirement of this specification for yield strength will be considered as having been fulfilled if the extension under load for the specified yield strength does not exceed the specified values. The values obtained in this manner should not, however, be taken as the actual yield strength for 0.2%. In case of dispute, the offset method of determining yield strength shall be used.

8.2 *Bend Test:*

8.2.1 Bend-test specimens shall withstand cold bending without cracking when subjected to either the free-bend method or the controlled-bend (V-block) method at the condition specified by Tables 3 or 4, respectively. Specimens shall be bent around a diameter equal to the product of the bend factor times the specified thickness of the test specimen. The choice of test method for materials in conditions other than annealed shall be at the option of the seller.

8.2.2 Free-bend test specimens shall be bent cold, either by pressure or by blows. However, in the case of dispute, tests shall be made by pressure.

8.2.3 Controlled-bend (V-block) test specimens shall be bent cold by means of V-blocks or a mating punch and die having an included angle of 45° and with proper curvature of surface at the bend areas to impart the desired shape and diameter of bend to the specimen.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS [NOTE (1)]

		Composition, %							
Type	UNS Designation	Carbon, max or range	Manganese, max or range	Phosphorus, max	Sulfur, max	Silicon, max	Chromium	Nickel	Other Elements
201	S20100	0.15	5.50–7.50	0.060	0.030	0.75	16.00–18.00	3.50–5.50	N 0.25 max
202	S20200	0.15	7.50–10.00	0.060	0.030	0.75	17.00–19.00	4.00–6.00	N 0.25 max
. . .	S20400	0.03	7.00–9.00	0.040	0.030	1.00	15.00–17.00	1.50–3.00	N 0.15–0.30
205	S20500	0.12–0.25	14.00–15.00	0.060	0.030	0.75	16.50–18.00	1.00–1.75	N 0.32–0.40
301	S30100	0.15	2.00	0.045	0.030	0.75	16.00–18.00	6.00–8.00	N 0.10 max
302	S30200	0.15	2.00	0.045	0.030	0.75	17.00–19.00	8.00–10.00	
304	S30400	0.08	2.00	0.045	0.030	0.75	18.00–20.00	8.00–10.50	N 0.10 max
304L	S30403	0.030	2.00	0.045	0.030	0.75	18.00–20.00	8.00–12.00	N 0.10 max
304N	S30451	0.08	2.00	0.045	0.030	0.75	18.00–20.00	8.00–10.50	N 0.10–0.16
304LN	S30453	0.030	2.00	0.045	0.030	0.75	18.00–20.00	8.00–12.00	N 0.10–0.16
316	S31600	0.08	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	Mo 2.00–3.00
316L	S31603	0.030	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	Mo 2.00–3.00
316N	S31651	0.08	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	Mo 2.00–3.00 N 0.10–0.16
XM-11	S21904	0.04	8.00–10.00	0.060	0.030	0.75	19.00–21.50	5.50–7.50	N 0.15–0.40
XM-14	S21460	0.12	14.00–16.00	0.060	0.030	0.75	17.00–19.00	5.00–6.00	N 0.35–0.50

NOTE:
(1) Types XM-10 and XM-19, which appeared in Specification A 412, do not appear as XM-10 is no longer produced and XM-19 is covered in Specification A 240/A 240M.

TABLE 2
TENSILE PROPERTY REQUIREMENTS [NOTE (1)]

Annealed

Type	UNS Designation	Tensile Strength, min psi	Tensile Strength, min MPa	Yield Strength, min psi	Yield Strength, min MPa	Elongation in 2 in. or 50 mm, min, %	Hardness, max Brinell	Hardness, max Rockwell B
201-1 [Note (2)]	S20100 Class 1	95 000	655	38 000	260	40	217	95
201-2	S20100 Class 2	95 000	655	45 000	310	40	255	100
202	S20200	90 000	620	38 000	260	40	...	...
...	S20400	95 000	655	48 000	330	35	255	100
205	S20500	115 000	790	65 000	450	40	255	100
301	S30100	90 000	620	30 000	205	40	217	95
302	S30200	75 000	515	30 000	205	40	201	92
304	S30400	75 000	515	30 000	205	40	201	92
304L	S30403	70 000	485	25 000	170	40	201	92
304N	S30451	80 000	550	35 000	240	40	217	95
304LN	S30453	80 000	550	35 000	240	40	217	95
316	S31600	75 000	515	30 000	205	40	217	95
316L	S31603	70 000	485	25 000	170	40	217	95
316N	S31651	80 000	550	35 000	240	40	217	95
XM-11	S21904 Sheet, Strip	100 000	690	60 000	415	40	...	...
	Plate	90 000	620	50 000	345	45	...	...
XM-14	S21460	105 000	725	55 000	380	40	...	...

1/16 Hard [Note (3)]

Type	UNS Designation	Tensile Strength, min psi	Tensile Strength, min MPa	Yield Strength, min psi	Yield Strength, min MPa	Elongation in 2 in. or 50 mm, min, % <0.015 in.	Elongation in 2 in. or 50 mm, min, % ≥0.015 to ≤0.030 in.	Elongation in 2 in. or 50 mm, min, % >0.030 in.
201	S20100 PSS [Note (4)]	95 000	655	45 000	310	40	40	40
	FB [Note (5)]	75 000	515	40 000	275	...	...	40
205	S20500	115 000	790	65 000	450	40	40	40
301	S30100	90 000	620	45 000	310	40	40	40
302	S30200 PSS	85 000	585	45 000	310	40	40	40
	FB	90 000	620	45 000	310	...	...	40
304	S30400 PSS	80 000	550	45 000	310	35	35	35
	FB	90 000	620	45 000	310	...	...	40
304L	S30403	80 000	550	45 000	310	40	40	40
304N	S30451	90 000	620	45 000	310	40	40	40
304LN	S30453	90 000	620	45 000	310	40	40	40
316	S31600 PSS	85 000	585	45 000	310	35	35	35
	FB	90 000	620	45 000	310	...	...	40
316L	S31603	85 000	585	45 000	310	35	35	35
316N	S31651	90 000	620	45 000	310	35	35	35

1/8 Hard [Note (3)]

Type	UNS Designation	Tensile Strength, min psi	Tensile Strength, min MPa	Yield Strength, min psi	Yield Strength, min MPa	Elongation in 2 in. or 50 mm, min, % <0.015 in.	Elongation in 2 in. or 50 mm, min, % ≥0.015 to ≤0.030 in.	Elongation in 2 in. or 50 mm, min, % >0.030 in.
201	S20100	100 000	690	55 000	380	45	45	45
205	S20500	115 000	790	65 000	450	40	40	40
301	S30100	100 000	690	55 000	380	40	40	40
302	S30200	100 000	690	55 000	380	35	35	35
304	S30400	100 000	690	55 000	380	35	35	35
304L	S30403	100 000	690	55 000	380	30	30	30
304N	S30451	100 000	690	55 000	380	37	37	37
304LN	S30453	100 000	690	55 000	380	33	33	33
316	S31600	100 000	690	55 000	380	30	30	30
316L	S31603	100 000	690	55 000	380	25	25	25
316N	S31651	100 000	690	55 000	380	32	32	32

TABLE 2 (CONT'D)
TENSILE PROPERTY REQUIREMENTS

		¼ Hard						
		Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
Type	UNS Designation	psi	MPa	psi	MPa	<0.015 in.	≥0.015 to ≤0.030 in.	>0.030 in.
201	S20100	125 000	860	75 000	515	25	25	25
202	S20200	125 000	860	75 000	515	12	12	. . .
. . .	S20400	140 000	965	100 000	960	20	20	20
205	S20500	125 000	860	75 000	515	45	45	45
301	S30100	125 000	860	75 000	515	25	25	25
302	S30200	125 000	860	75 000	515	10	10	12
304	S30400	125 000	860	75 000	515	10	10	12
304L	S30403	125 000	860	75 000	515	8	8	10
304N	S30451	125 000	860	75 000	515	12	12	12
304LN	S30453	125 000	860	75 000	515	10	10	12
316	S31600	125 000	860	75 000	515	10	10	10
316L	S31603	125 000	860	75 000	515	8	8	8
316N	S31651	125 000	860	75 000	515	12	12	12
XM-11	S21904	130 000	895	115 000	795	15	15	. . .

		½ Hard						
		Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
Type	UNS Designation	psi	MPa	psi	MPa	<0.015 in.	≥0.015 to ≤0.030 in.	>0.030 in.
201	S20100	150 000	1035	110 000	760	15	18	18
205	S20500	150 000	1035	110 000	760	15	18	18
301	S30100	150 000	1035	110 000	760	15	18	18
302	S30200	150 000	1035	110 000	760	9	10	10
304	S30400	150 000	1035	110 000	760	6	7	7
304L	S30403	150 000	1035	110 000	760	5	6	6
304N	S30451	150 000	1035	110 000	760	6	8	8
304LN	S30453	150 000	1035	110 000	760	6	7	7
316	S31600	150 000	1035	110 000	760	6	7	7
316L	S31603	150 000	1035	110 000	760	5	6	6
316N	S31651	150 000	1035	110 000	760	6	8	8

		¾ Hard						
		Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
Type	UNS Designation	psi	MPa	psi	MPa	<0.015 in.	≥0.015 to ≤0.030 in.	>0.030 in.
201	S20100	175 000	1205	135 000	930	10	12	12
205	S20500	175 000	1205	135 000	930	15	15	15
301	S30100	175 000	1205	135 000	930	10	12	12
302	S30200	175 000	1205	135 000	930	5	6	6

		Full Hard						
		Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %		
Type	UNS Designation	psi	MPa	psi	MPa	<0.015 in.	≥0.015 to ≤0.030 in.	>0.030 in.
201	S20100	185 000	1275	140 000	965	8	9	9
205	S20500	185 000	1275	140 000	965	10	10	10
301	S30100	185 000	1275	140 000	965	8	9	9
302	S30200	185 000	1275	140 000	965	3	4	4

(1) This specification defines minimum properties only and does not imply a range. Depending on the work hardening characteristics of the particular grade, either the yield or the tensile strength can be the controlling factor in meeting the properties. The noncontrolling factor normally will exceed considerably the specified minimum.
(2) Type 201 is generally produced with a chemical composition balanced for rich side (Type 201-1) or lean side (Type 201-2) austenite stability depending on the properties required for specific applications.
(3) Annealed material that naturally meets mechanical properties may be applied.
(4) PSS means plate, strip, sheet.
(5) FB means flat bar.

TABLE 3
FREE BEND REQUIREMENTS

Annealed and 1/16 and 1/8 Hard					
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	1	180	1
202	S20200	180	1	180	1
...	S20400	180	1	180	1
205	S20500	180	1	180	1
301	S30100	180	1	180	1
302	S30200	180	1	180	1
304	S30400	180	1	180	1
304L	S30403	180	1	180	2
304N	S30451	180	1	180	1
304LN	S30453	180	1	180	2
316	S31600	180	1	180	2
316L	S31603	180	1	180	2
316N	S31651	180	1	180	1
XM-11	S21904	180	1	180	1
XM-14	S21460	180	1	180	2
1/4 Hard					
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	1	90	2
202	S20200	180	2	90	2
...	S20400	180	1	90	2
205	S20500	180	1	90	2
301	S30100	180	1	90	2
302	S30200	180	1	90	2
304	S30400	180	1	90	2
304L	S30403	180	2	90	3
304N	S30451	180	1	90	2
304LN	S30453	180	2	90	3
316	S31600	180	2	90	2
316L	S31603	180	2	90	3
316N	S31651	180	1	90	2
XM-11	S21904	90	2	90	2
1/2 Hard					
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	2	90	2
205	S20500	180	2	90	2
301	S30100	180	2	90	2
302	S30200	180	2	90	2
304	S30400	180	2	90	2
304L	S30403	180	3	90	3
304N	S30451	180	2	90	2
304LN	S30453	180	3	90	3
316	S31600	180	3	90	3
316L	S31603	180	3	90	3
316N	S31651	180	2	90	2

TABLE 3 (CONT'D)
FREE BEND REQUIREMENTS

		¾ Hard			
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	3	90	3
205	S20500	180	3	90	3
301	S30100	180	3	90	3
302	S30200	180	4	90	5
		Full Hard			
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	180	4	90	5
205	S20500	180	4	90	5
301	S30100	180	4	90	5
302	S30200	180	6	90	8

TABLE 4
V-BLOCK BEND REQUIREMENTS

		Annealed and ⅛ Hard			
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	2	135	3
202	S20200	135	4	135	4
205	S20500	135	2	135	3
301	S30100	135	2	135	3
302	S30200	135	2	135	3
304	S30400	135	2	135	3
304L	S30403	135	5	135	6
304N	S30451	135	3	135	4
304LN	S30453	135	4	135	5
316	S31600	135	5	135	6
316L	S31603	135	6	135	7
316N	S31651	135	5	135	6
		¼ Hard			
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	2	135	3
205	S20500	135	2	135	3
301	S30100	135	2	135	3
302	S30200	135	2	135	3
304	S30400	135	2	135	3
304L	S30403	135	5	135	6
304N	S30451	135	3	135	4
304LN	S30453	135	4	135	5
316	S31600	135	5	135	6
316L	S31603	135	6	135	7
316N	S31651	135	5	135	6

TABLE 4 (CONT'D)
V-BLOCK BEND REQUIREMENTS

		½ Hard			
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	4	135	4
205	S20500	135	4	135	4
301	S30100	135	4	135	4
302	S30200	135	4	135	4
304	S30400	135	4	135	4
304L	S30403	135	7	135	8
304N	S30451	135	5	135	6
304LN	S30453	135	6	135	7
316	S31600	135	7	135	8
316L	S31603	135	8	135	9
316N	S31651	135	7	135	8
		¾ Hard			
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	6	135	7
205	S20500	135	6	135	7
301	S30100	135	6	135	7
302	S30200	135	8	135	9
		Full Hard			
		Thickness ≤0.050 in.		Thickness >0.050 to ≤0.1874 in.	
Type	UNS Designation	Included Bend Angle,°	Bend Factor	Included Bend Angle,°	Bend Factor
201	S20100	135	6	135	8
205	S20500	135	6	135	8
301	S30100	135	6	135	8
302	S30200	135	8	135	10

SPECIFICATION FOR CENTRIFUGALLY CAST DUAL METAL (GRAY AND WHITE CAST IRON) CYLINDERS

SA-667/SA-667M

(Identical with ASTM Specification A 667/A 667M-87.)

1. Scope

1.1 This specification covers centrifugally cast cylinders with an outer layer of white cast iron and the remainder of the material of gray cast iron. These castings are suitable for pressure containing parts the design strength of which is based on the gray iron portion of the cylinder. These castings are suitable for service at temperatures up to 450°F [230°C].

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 278 Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F

A 278M Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 345°C [Metric]

3. Materials and Manufacture

3.1 The melting procedures shall be optional with the foundry.

3.2 The white iron portion of the cylinder shall be made to a minimum hardness of 55 Scleroscope ‘‘C’’. The gray iron portion of the cylinder shall conform to Specification A 278, Class 20 [A 278M, Class 150].

3.3 The casting process shall be controlled to produce a metallurgical bond between the two metal layers.

4. Physical Requirements

4.1 *Tensile Requirements* — Tension test specimens removed from the casting shall have a tensile strength not less than 80% of that specified in 3.2.

4.2 *Thickness of White Cast Iron:*

4.2.1 The thickness of the white cast iron shall be not less than 5% nor more than 30% of the total finished wall thickness.

4.2.2 The thickness of the white cast iron shall be determined by ultrasonic testing.

5. Finish

5.1 All surfaces shall be machined prior to the cylinders being placed into service.

6. Number of Tests

6.1 The number of tension tests shall be in conformance with Specifications A 278 and A 278M.

7. Specimen Preparation

7.1 Separately cast test bars may be used to represent the gray iron portion of the castings. The test bars shall be cast in core sand and have a nominal diameter of 2 in. [50 m]. Tension test specimens shall be machined from test bars to the dimensions given for Specimen C in Specifications A 278 and A 278M.

7.2 At the option of the manufacturer he may substitute test bars taken from the gray iron portion of the casting. The test bars shall be taken midway between the inside diameter of the casting and the interface between the two layers. Tension test specimens machined from these test bars shall conform to the dimensions shown for Specimen C in Specifications A 278 and A 278M.

8. Test Method

8.1 Tension test specimens shall fit the holders of the testing machine in such a way that the load shall be axial. The use of self-aligning shackles is suggested. After reaching a stress equivalent to 15 000 psi [100 MPa] the speed of the moving head of the testing machine shall not exceed $\frac{1}{8}$ in. [3.2 mm]/min.

9. Inspection

9.1 The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector without charge all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections shall be made at the place of manufacture prior to the shipment unless otherwise specified and shall be so conducted as not to interfere unnecessarily with the operation of the works.

10. Acceptance and Certification

10.1 Final acceptance of the casting shall follow complete machining of the casting. Upon request of the purchaser and when so specified in the purchase order, a certification shall be made on the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the supplier accompanied by a copy of the test results that the material has been sampled, tested, and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

11. Product Marking

11.1 Pressure containing castings made in accordance with this specification shall have the name of the manufacturer or his recognized trademark and the class of iron to which it conforms cast or indelibly stamped on the surface indicated by the purchaser or in such a position as not to injure the usefulness of the casting.

SPECIFICATION FOR ELECTRIC-FUSION-WELDED STEEL PIPE FOR ATMOSPHERIC AND LOWER TEMPERATURES

SA-671

(Identical to ASTM Specification A 671-94 except that the following additional requirements apply.) 98

All products furnished under this SA specification are intended for application under the rules of Section III of the ASME Boiler and Pressure Vessel Code. Manufacture of such products is limited to manufacturers who hold the appropriate ASME Certificate of Authorization and Code Symbol Stamp. In addition to conforming to this specification, the manufacturer shall meet all applicable requirements of Section III of the Code. The plate used to fabricate the pipe shall conform to the applicable SA specification in ASME Boiler and Pressure Vessel Code, Section II. The joints shall be full penetration butt welds as obtained by double welding or by other means which will obtain the same quality of deposited and weld metal on the inside and outside. Welds using metal backing strips which remain in place are excluded. The product is subject to all requirements of Section III of the Code including welding, heat treatment, nondestructive examination, authorized inspection at the point of manufacture, and application of the Code Symbol Stamp.

The applicable ASME Partial Data Report Form, signed by an Authorized Inspector, and a certified mill test report shall be furnished for each lot of pipe as defined by requirement S14 of this specification. Each length of pipe shall be marked in such a manner as to identify each piece with the lot and the certified mill test report

1. Scope

1.1 This specification covers electric-fusion-welded steel pipe with filler metal added, fabricated from pressure vessel quality plate of several analyses and strength levels and suitable for high-pressure service at atmospheric and lower temperatures. Heat treatment may or may not be required to attain the desired properties or to comply with applicable code requirements. Supplementary requirements are provided for use when additional testing or examination is desired.

1.2 The specification nominally covers pipe 16 in. (405 mm) in outside diameter or larger and of ¼ in. (6.4 mm) wall thickness or greater. Pipe having other dimensions may be furnished provided it complies with all other requirements of this specification.

1.3 Several grades and classes of pipe are provided.

1.3.1 Grade designates the type of plate used as listed in Table 1.

1.3.2 Class designates the type of heat treatment performed during manufacture of the pipe, whether the weld is radiographically examined, and whether the pipe has been pressure tested as listed in 1.3.3.

1.3.3 Class designations are as follows (Note):

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see:
10	none	none	none
11	none	9	none
12	none	9	8.3
13	none	none	8.3
20	stress relieved, see 6.3.1	none	none
21	stress relieved, see 6.3.1	9	none
22	stress relieved, see 6.3.1	9	8.3
23	stress relieved, see 6.3.1	none	8.3
30	normalized, see 6.3.2	none	none
31	normalized, see 6.3.2	9	none
32	normalized, see 6.3.2	9	8.3
33	normalized, see 6.3.2	none	8.3

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see:
40	normalized and tempered, see 6.3.3	none	none
41	normalized and tempered, see 6.3.3	9	none
42	normalized and tempered, see 6.3.3	9	8.3
43	normalized and tempered, see 6.3.3	none	8.3
50	quenched and tempered, see 6.3.4	none	none
51	quenched and tempered, see 6.3.4	9	none
52	quenched and tempered, see 6.3.4	9	8.3
53	quenched and tempered, see 6.3.4	none	8.3
60	normalized and precipitation heat treated	none	none
61	normalized and precipitation heat treated	9	none
62	normalized and precipitation heat treated	9	8.3
63	normalized and precipitation heat treated	none	8.3
70	quenched and precipitation heat treated	none	none
71	quenched and precipitation heat treated	9	none
72	quenched and precipitation heat treated	9	8.3
73	quenched and precipitation heat treated	none	8.3

NOTE—Selection of materials should be made with attention to temperature of service. For such guidance, Specification A 20/A 20M may be consulted.

1.4 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

2.1.1 *General:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

E 110 Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers

E 165 Practice for Liquid Penetrant Inspection Method

E 350 Method for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

E 709 Practice for Magnetic Particle Examination

2.1.2 *Plate Steels:*

A 203/A 203M Specification for Pressure Vessel Plates, Alloy Steel, Nickel

A 285/A 285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength

A 299/A 299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon

A 353/A 353M Specification for Pressure Vessel Plates, Alloy Steel, 9 Percent Nickel, Double-Normalized and Tempered

A 442/A 442M Specification for Pressure Vessel Plates, Carbon Steel, Improved Transition Properties

A 515/A 515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate-and Higher-Temperature Service

A 516/A 516M Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service

A 517/A 517M Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered

A 537/A 537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel

A 553/A 553M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9 Percent Nickel

A 645/A 645M Specification for Pressure Vessel Plates, 5 Percent Nickel Alloy Steel, Specially Heat Treated

A 736/A 736M Specification for Pressure Vessel Plates, Low-Carbon Age-Hardening, Nickel-Copper-Chromium-Molybdenum-Columbium Alloy Steel

2.2 *ASME Boiler and Pressure Vessel Code:*

Section II, Material Specifications

Section III, Nuclear Vessels

Section VIII, Unfired Pressure Vessels

Section IX, Welding Qualifications

3. Terminology

3.1 *Description of a Term Specific to This Standard:*

3.1.1 *lot*—a lot shall consist of 200 ft (61 m) or fraction thereof of pipe from the same heat of steel.

3.1.2 The description of a lot may be further restricted by the use of Supplementary Requirement S14.

4. Ordering Information

4.1 The inquiry and order for material under this specification shall include the following information:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (steel pipe, electric-fusion-welded),

4.1.3 Specification number,

4.1.4 Grade and class designations (see 1.3),

4.1.5 Size (inside or outside diameter, nominal or minimum wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish (11.4),

4.1.8 Purchase options, if any (see 5.2.3, 11.3, 14.1 of this specification and Sections 16, 20.1, 21, and 22 of Specification A 530/A 530M),

4.1.9 Supplementary requirements, if any.

5. Materials and Manufacture

5.1 *Materials*—The steel plate material shall conform to the requirement of the applicable plate specification for the pipe grade ordered as listed in Table 1.

5.2 *Welding:*

5.2.1 The joints shall be double-welded, full-penetration welds made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

5.2.2 The welds shall be made either manually or automatically by an electric process involving the deposition of filler metal.

5.2.3 As welded, the welded joint shall have positive reinforcement at the center of each side of the weld, but no more than $\frac{1}{8}$ in. (3.2 mm). This reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be smooth and the deposited metal shall be fused smoothly and uniformly into the plate surface.

5.2.4 When radiographic examination in accordance with 9.1 is to be used, the weld reinforcements shall be governed by the more restrictive provision UW-51 of Section VIII of the ASME Boiler and Pressure Vessel Code instead of 5.2.3 of this specification.

5.3 *Heat Treatment*—All classes other than 10, 11, 12, and 13 shall be heat treated in furnace controlled to ±25°F (±14°C) and equipped with a recording pyrometer so that heating records are available. Heat treating after forming and welding shall be to one of the following:

5.3.1 Classes 20, 21, 22, and 23 pipe shall be uniformly heated within the post-weld heat-treatment temperature range indicated in Table 2 for a minimum of 1 h/in. of thickness or for 1 h, whichever is greater.

5.3.2 Classes 30, 31, 32, and 33, pipe shall be uniformly heated to a temperature in the austenitizing range and not exceeding the maximum normalizing temperature indicated in Table 2 and subsequently cooled in air at room temperature.

5.3.3 Classes 40, 41, 42, and 43 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of $\frac{1}{2}$ h/in. of thickness or for $\frac{1}{2}$ h, whichever is greater, and air cooled.

5.3.4 Classes 50, 51, 52, and 53 pipe shall be uniformly heated to a temperature in the austenitizing range, and not exceeding the maximum quenching temperature indicated in Table 2 and subsequently quenched in water or oil. After quenching, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at that temperature for a minimum of $\frac{1}{2}$ h/in. of thickness or for $\frac{1}{2}$ h, whichever is greater, and air cooled.

5.3.5 Classes 60, 61, 62, and 63 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be precipitation heat treated in the range shown in Table 2 for a time to be determined by the manufacturer.

5.3.6 Classes 70, 71, 72, and 73 pipe shall be uniformly heated to a temperature in the austenitizing range, not exceeding the maximum quenching temperature indicated in Table 2, and subsequently quenched in water or oil. After quenching the pipe shall be reheated into the precipitation heat treating range indicated in Table 2 for a time to be determined by the manufacturer.

6. General Requirements for Delivery

6.1 Only the following sections of Specification A 530/A 530M shall apply: 1, 2, 7, 8, 14, 16, 17, 19, 20, 21, and 22. Section 6 of Specification A 530/A 530M shall apply only for classes requiring hydrostatic testing.

7. Chemical Composition

7.1 *Product Analysis of Plate*—The pipe manufacturer shall make an analysis of each mill heat of plate material. The product analysis so determined shall meet the requirements of the plate specification to which the material was ordered.

7.2 *Product Analyses of Weld*—The pipe manufacturer shall make an analysis of finished deposited weld material from each 200 ft (61 m) or fraction thereof. Analyses shall conform to the welding procedure for deposited weld metal.

7.3 Analysis may be taken from the mechanical test specimens. The results of the analyses shall be reported to the purchaser.

8. Mechanical Requirements

8.1 *Tension Test:*

8.1.1 *Requirements*—Transverse tensile properties of the welded joint shall meet the minimum requirements for ultimate tensile strength of the specified plate material. In addition for Grades CD and CJ, when these are of Class 3x, 4x, or 5x, and Grade CP of Class 6x and 7x, the transverse tensile properties of the base plate shall be determined on specimens cut from the heat-treated pipe. These properties shall meet the mechanical test requirements of the plate specification.

8.1.2 *Number of Tests*—One test specimen of weld metal and one specimen of base metal, if required by 8.1.1, shall be made and tested to represent each lot of finished pipe.

8.1.3 *Test Specimen Location and Orientation*—The test specimens shall be taken transverse to the weld at the end of the finished pipe and may be flattened cold before final machining to size.

8.1.4 *Test Method*—The test specimen shall be made in accordance with QW-150 in Section IX of the ASME Boiler and Pressure Vessel Code. The test specimen shall be tested at room temperature in accordance with Methods and Definitions A 370.

8.2 *Transverse Guided Weld Bend Test:*

8.2.1 *Requirements*—The bend test shall be acceptable if no cracks or other defects exceeding $\frac{1}{8}$ in. (3.2 mm) in any direction are present in the weld metal or between the weld and the base metal after bending. Cracks that originate along the edges of the specimen during testing, and that are less than $\frac{1}{4}$ in. (6.4 mm) measured in any direction shall not be considered.

8.2.2 *Number of Tests*—One test (two specimens) shall be made to represent each lot of finished pipe.

8.2.3 *Test Specimen Location and Orientation*—Two bend test specimens shall be taken transverse to the weld at the end of the finished pipe. As an alternative, by agreement between the purchaser and the manufacturer, the test specimens may be taken from a test plate of the same material as the pipe, the test plate being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

8.2.4 *Test Method*—The test requirements of A 370, S9.1.7 shall be met. For wall thicknesses over $\frac{3}{8}$ in. (9.5 mm) but less than $\frac{3}{4}$ in. (19.0 mm) side-bend tests may be made instead of the face and root-bend tests. For wall thicknesses $\frac{3}{4}$ in. and over both specimens shall be subjected to the side-bend test.

8.3 *Pressure Test*—Classes X2 and X3 pipe shall be tested in accordance with Specification A 530/A 530M, Section 6.

9. Radiographic Examination

9.1 The full length of each weld of Classes X1 and X2 shall be radiographically examined in accordance with and meet the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Paragraph UW-51.

9.2 Radiographic examination may be performed prior to heat treatment.

10. Rework

10.1 *Elimination of Surface Imperfections*—Unacceptable surface imperfections shall be removed by grinding or machining. The remaining thickness of the section shall be no less than the minimum specified in Section 11. The depression after grinding or machining shall be blended uniformly into the surrounding surface.

10.2 *Repair of Base Metal Defects by Welding:*

10.2.1 The manufacturer may repair, by welding, base metal where defects have been removed, provided the depth of the repair cavity as prepared for welding, does not exceed $\frac{1}{3}$ of the nominal thickness and the requirements of 10.2.2, 10.2.3, 10.2.4, 10.2.5, and 10.2.6, are met. Base metal defects in excess of these may be repaired with prior approval of the customer.

10.2.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair welding.

10.2.3 The welding procedure and welders or welding operators are to be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.2.4 The full length of the repaired pipe shall be heat treated after repair in accordance with the requirements of the pipe class specified.

10.2.5 Each repair weld of a defect where the cavity, prepared for welding, has a depth exceeding the lesser of $\frac{3}{8}$ in. (9.5 mm) or 10% of the nominal thickness shall be examined by radiography in accordance with the methods and the acceptance standards of Section 9.

10.2.6 The repair surface shall be blended uniformly into the surrounding base metal surface and examined and accepted in accordance with Supplementary Requirements S6 or S8.

10.3 *Repair of Weld Metal Defects by Welding:*

10.3.1 The manufacturer may repair weld metal defects if he meets the requirements of 10.2.3, 10.2.4, 10.3.2, 10.3.3, and 10.4.

10.3.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the repair cavity examined and accepted in accordance with Supplementary Requirements S7 or S9.

10.3.3 The weld repair shall be blended uniformly into the surrounding metal surfaces and examined and accepted in accordance with 9.1 and with Supplementary Requirements S7 or S9.

10.4 *Retest*—Each length of repaired pipe of a class requiring a pressure test shall be hydrostatically tested following repair.

11. Dimensions, Mass, and Permissible Variations

11.1 The wall thickness and weight for welded pipe furnished to this specification shall be governed by the requirements of the specification to which the manufacturer ordered the plate.

11.2 Permissible variations in dimensions at any point in a length of pipe shall not exceed the following:

11.2.1 *Outside Diameter*—Based on circumferential measurement + 0.5% of the specified outside diameter.

11.2.2 *Out-of-Roundness*—Difference between major and minor outside diameters, 1%.

11.2.3 *Alignment*—Using a 10 ft (3 m) straight edge placed so that both ends are in contact with the pipe, $\frac{1}{8}$ in. (3.2 mm).

11.2.4 *Thickness*—The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. (0.25 mm) under the specified nominal thickness.

11.3 Circumferential welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

11.4 Lengths with unmachined ends shall be within −0, +$\frac{1}{2}$ in. (−0, +13 mm) of that specified. Lengths with machined ends shall be as agreed between the manufacturer and the purchaser.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall be free of injurious defects and shall have a workmanlike finish. This requirement is to mean the same as the identical requirement that appears in Specification A 20/A 20M with respect to steel plate surface finish.

13. Product Marking

13.1 In addition to the marking provision of Specification A 530/A 530M, class marking in accordance with 1.3.3 shall follow the grade marking, for example, CC 70-10.

13.2 *Bar Coding*—In addition to the requirements in 13.1, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

TABLE 1
PLATE SPECIFICATIONS

		ASTM Specification	
Pipe Grade	Type of Steel	No.	Grade
CA 55	plain carbon	A 285/A 285M	C
CB 60	plain carbon, killed	A 515/A 515M	60
CB 65	plain carbon, killed	A 515/A 515M	65
CB 70	plain carbon, killed	A 515/A 515M	70
CC 60	plain carbon, killed, fine grain	A 516/A 516M	60
CC 65	plain carbon, killed, fine grain	A 516/A 516M	65
CC 70	plain carbon, killed, fine grain	A 516/A 516M	70
CD 70	manganese-silicon, normalized	A 537/A 537M	1
CD 80	manganese-silicon, quenched and tempered	A 537/A 537M	2
CE 55	plain carbon	A 442/A 442M	55
CE 60	plain carbon	A 442/A 442M	60
CF 65	nickel steel	A 203/A 203M	A
CF 70	nickel steel	A 203/A 203M	B
CF 66	nickel steel	A 203/A 203M	D
CF 71	nickel steel	A 203/A 203M	E
CJ 101	alloy steel, quenched and tempered	A 517/A 517M	A
CJ 102	alloy steel, quenched and tempered	A 517/A 517M	B
CJ 103	alloy steel, quenched and tempered	A 517/A 517M	C
CJ 104	alloy steel, quenched and tempered	A 517/A 517M	D
CJ 105	alloy steel, quenched and tempered	A 517/A 517M	E
CJ 106	alloy steel, quenched and tempered	A 517/A 517M	F
CJ 107	alloy steel, quenched and tempered	A 517/A 517M	G
CJ 108	alloy steel, quenched and tempered	A 517/A 517M	H
CJ 109	alloy steel, quenched and tempered	A 517/A 517M	J
CJ 110	alloy steel, quenched and tempered	A 517/A 517M	K
CJ 111	alloy steel, quenched and tempered	A 517/A 517M	L
CJ 112	alloy steel, quenched and tempered	A 517/A 517M	M
CJ 113	alloy steel, quenched and tempered	A 517/A 517M	P
CK 75	carbon-manganese-silicon	A 299/A 299M	
CP65	alloy steel, age hardening, normalized and precipitation heat treated	A 736/A 736M	2
CP75	alloy steel, age hardening, quenched and precipitation heat treated	A 736/A 736M	3

TABLE 2
HEAT TREATMENT PARAMETERS

Pipe Grade[A]	ASTM Specification and Grade	Post-Weld Heat-Treatment Temperature Range °F (°C)	Normalizing Temperature, max, °F (°C)	Quenching Temperature, max, °F (°C)	Tempering Temperature, min, °F (°C)	Precipitation Heat Treatment Temperature Range °F (°C)
CA 55	A 285/A 285M (C)	1100–1250 (590–680)	1700 (925)	...	...	...
CB 60	A 515/A 515M (60)	1100–1250 (590–680)	1750 (950)	...	...	...
CB 65	A 515/A 515M (65)	1100–1250 (590–680)	1750 (950)	...	...	...
CB 70	A 515/A 515M (70)	1100–1250 (590–680)	1750 (950)	...	...	...
CC 60	A 516/A 516M (60)	1100–1250 (590–680)[B]	1700 (925)	1650 (900)	1200 (650)[D]	...
CC 65	A 516/A 516M (65)	1100–1250 (590–680)[B]	1700 (925)	1650 (900)	1200 (650)	...
CC 70	A 516/A 516M (70)	1100–1250 (590–680)[B]	1700 (925)	1650 (900)	1200 (650)	...
CD 70	A 537/A 537M (1)	1100–1250 (590–680)	1700 (925)	...	...	...
CD 80	A 537/A 537M (2)	1100–1250 (590–680)[B]	...	1650 (900)	1100 (590)	...
CE 55	A 442/A 442M (55)	1100–1250 (590–680)[B]	1700 (925)	1650 (900)	1200 (650)	...
CE 60	A 442/A 442M (60)	1100–1250 (590–680)[B]	1700 (925)	1650 (900)	1200 (650)	...
CF 65	A 203/A 203M (A)	1100–1175 (590–635)	1750 (950)	...	...	...
CF 70	A 203/A 203M (B)	1100–1175 (590–635)	1750 (950)	...	...	...
CF 66	A 203/A 203M (D)	1100–1175 (590–635)	1750 (950)	...	...	...
CF 71	A 203/A 203M (E)	1100–1175 (590–635)	1750 (950)	...	...	...
CJ 101	A 517/A 517M (A)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CJ 102	A 517/A 517M (B)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CJ 103	A 517/A 517M (C)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CJ 104	A 517/A 517M (D)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CJ 105	A 517/A 517M (E)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CJ 106	A 517/A 517M (F)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CJ 107	A 517/A 517M (G)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CJ 108	A 517/A 517M (H)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CJ 109	A 517/A 517M (J)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CJ 110	A 517/A 517M (K)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CJ 111	A 517/A 517M (L)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CJ 112	A 517/A 517M (M)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CJ 113	A 517/A 517M (P)	1000–1100 (540–590)	...	1725 (940)[C]	1150 (620)	...
CK 75	A 299/A 299M	1100–1250 (590–680)	1700 (925)	...	...	...
CP65	A 736/A736M (2)	1000–1175 (540–635)	1725 (940)	...	...	1000–1200 (540–650)
CP75	A 736/A 736M (3)	1000–1175 (540–635)	...	1725 (940)	...	1000–1225 (540–665)

[A] Numbers indicate minimum tensile strength in ksi.
[B] In no case shall the post-weld heat-treatment temperature exceed the mill tempering temperature.
[C] Per ASME Section VIII Specification A 517/A 517M specified 1650 (900) minimum quenching temperature.
[D] Tempering range 1100 to 1300, if acclerated cooling utilized per Specification A 516/A 516M.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Tension and Bend Tests

S1.1 Tension tests in accordance with 8.1 and bend tests in accordance with 8.2 shall be made on specimens representing each length of pipe.

S2. Charpy V-Notch Test

S2.1 *Requirements*—The acceptable test energies for material shown in Specification A 20/A 20M shall conform to the energy values shown in Specification A 20/A 20M.

S2.1.1 Materials not listed in Specification A 20/A 20M shall be in accordance with the purchase order requirements.

S2.2 *Number of Specimens*—Each test shall consist of at least three specimens.

S2.2.1 One base metal test shall be made from one pipe length per heat-treat charge per nominal wall thickness.

S2.2.2 One weld-metal test shall be made in accordance with UG-84 of Section VIII of the ASME Boiler and Pressure Vessel Code.

S2.2.3 One heat-affected-zone test shall be made in accordance with UG-84 of Section VIII of the ASME Boiler and Pressure Vessel Code.

S2.3 *Test Specimen Location and Orientation:*

S2.3.1 Specimens for base-metal tests in Grades CA, CB, CC, and CE in the stress relieved or normalized condition (classes of the 20, 30, and 40 series) shall be taken so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the pipe.

S2.3.2 Base-metal specimens of quench and tempered pipe, when the quenching and tempering follows the welding operation, shall be taken in accordance with the provision of N330 of Section III of the ASME Boiler and Pressure Vessel Code.

S2.4 *Test Method*—The specimen shall be Charpy-V Type A in accordance with Methods and Definitions A 370. The specimens shall be tested in accordance with Methods and Definitions A 370. Unless otherwise indicated by the purchaser, the test temperature shall be as given in Specification A 20/A 20M for those base materials covered by Specification A 20/A 20M. For materials not covered by Specification A 20/A 20M the test temperature shall be 10°F (−12°C) unless otherwise stated in the purchase order.

S3. Hardness Test

S3.1 Hardness tests shall be made in accordance with Methods and Definitions A 370 or Test Method E 110 across the welded joint of both ends of each length of pipe. In addition, hardness tests shall be made to include the heat-affected zone if so required by the purchaser. The maximum acceptable hardness shall be as agreed upon between the manufacturer and the purchaser.

S3.2 As an alternative to the heat-affected zone hardness, by agreement between the manufacturer and purchaser, maximum heat-affected zone hardness may be specified for the procedure test results.

S4. Product Analysis

S4.1 Product analyses in accordance with 7.1 shall be made on each 500 ft (152 m) of pipe of fraction thereof, or alternatively, on each length of pipe as designated in the order.

S5. Metallography

S5.1 The manufacturer shall furnish one photomicrograph to show the microstructure at 100× magnification of the weld metal or base metal of the pipe in the as-finished condition. The purchaser shall state in the

order: the material, base metal or weld, and the number and locations of tests to be made. This test is for information only.

S6. Magnetic Particle Examination of Base Metal

S6.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E 709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. (610 mm) in diameter and greater, and inside surfaces of pipe less than 24 in. in diameter for a distance of 1 pipe diameter from the ends.

S6.2 *Acceptance Standards*—The following relevant indications are unacceptable:

S6.2.1 Any linear indications greater than $^{1}/_{16}$ in. (1.6 mm) long for materials less than $^{5}/_{8}$ in (15.9 mm) thick; greater than $^{1}/_{8}$ in. (3.2 mm) long for materials from $^{5}/_{8}$ in. thick to under 2 in. (51 mm) thick; and greater than $^{3}/_{16}$ in. (4.8 mm) long for materials 2 in. thick or greater.

S6.2.2 Rounded indications with dimensions greater than $^{1}/_{8}$ in. (3.2 mm) for thicknesses less than $^{5}/_{8}$ in. (15.9 mm), and greater than $^{3}/_{16}$ in. (4.8 mm) for thicknesses $^{5}/_{8}$ in. and greater.

S6.2.3 Four or more indications in any line separated by $^{1}/_{16}$ in. (1.6 mm) or less edge-to-edge.

S6.2.4 Ten or more indications in any 6 in.^{2} (39 cm^2) of surface with the major dimension of this area not to exceed 6 in. (152 mm) when it is taken in the most unfavorable orientation relative to the indications being evaluated.

S7. Magnetic Particle Examination of Weld Metal

S7.1 All accessible welds shall be examined in accordance with Practice E 709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. (610 mm) in diameter and greater, and inside surfaces of pipe less than 24 in. in diameter for a distance of one pipe diameter from the ends.

S7.2 *Acceptance Criteria*—The following relevant indications are unacceptable:

S7.2.1 Any cracks and linear indications.

S7.2.2 Rounded indications with dimensions greater than $^{3}/_{16}$ in. (4.8 mm).

S7.2.3 Four or more indications in any line separated by $^{1}/_{16}$ in. (1.6 mm) or less edge-to-edge.

S7.2.4 Ten or more indications in any 6 in.^{2} (39 cm^2) of surface with the major dimension of this area not to exceed 6 in. (152 mm) when it is taken in the most unfavorable orientation relative to the indications being evaluated.

S8. Liquid Penetrant Examination of Base Metal

S8.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E 165. Accessible is as defined in S7.1.

S8.2 The acceptance criteria shall be in accordance with S6.2.

S9. Liquid Penetrant Examination of Weld Metal

S9.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E 165. Accessible is as defined in S7.1.

S9.2 The acceptance criteria shall be in accordance with S7.2.

S10. Straight Beam Ultrasonic Examination of Flat Plate—UT 1

S10.1 The plate shall be examined and accepted in accordance with Specification A 435/A 435M except that 100% of one surface shall be scanned by moving the search unit in parallel paths with not less than 10% overlap.

S11. Straight Beam Ultrasonic Examination of Flat Plate—UT 2

S11.1 The plate shall be examined in accordance with Specification A 578/A 578M except that 100% of one surface shall be scanned and the acceptance criteria shall be as follows:

S11.1.1 Any area, where one or more discontinuities produce a continuous total loss of back reflection accompanied by continuous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. (76.2 mm) or one half of the plate thickness, whichever is greater, is unacceptable.

S11.1.2 In addition, two or more discontinuities on the same plane and having the same characteristics but smaller than described above shall be unacceptable unless separated by a minimum distance equal to the largest diameter of the larger discontinuity or unless they may be collectively encompassed by the circle described above.

S12. Angle Beam Ultrasonic Examination [Plate Less than 2 in. (50.8 mm) Thick]—UT 3

S12.1 The plate shall be examined in accordance with Specification A 577/A 577M except that the calibration notch shall be vee shaped and the acceptance criteria shall be as follows: Any area showing one or more reflections producing indications whose amplitude exceeds that of the calibration notch is unacceptable.

S13. Repair Welding

S13.1 Repair of base metal defects by welding shall be done only with customer approval.

S14. Description of Term

S14.1 *lot*—all pipe of the same mill heat of plate material and wall thickness [within $\pm 1/4$ in. (6.4 mm)] heat treated in one furnace charge. For pipe that is not heat treated or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft (61 m) or fraction thereof of all pipe of the same mill heat of plate material and wall thickness [within $\pm 1/4$ in. (6.4 mm)], subjected to the same heat treatment. For pipe heat treated in a batch-type furnace that is automatically controlled within a 50°F (28°C) range and is equipped with recording pyrometers so that heating records are available, a lot shall be defined the same as for continuous furnaces.

SPECIFICATION FOR ELECTRIC-FUSION-WELDED STEEL PIPE FOR HIGH-PRESSURE SERVICE AT MODERATE TEMPERATURES

SA-672

(Identical to ASTM Specification A 672-94 except for the deletion of pipe Grade K. The following additional requirements apply.) 98

All products furnished under this SA specification are intended for application under the rules of Section III of the ASME Boiler and Pressure Vessel Code. Manufacture of such products is limited to manufacturers who hold the appropriate ASME Certificate of Authorization and Code Symbol Stamp. In addition to conforming to this specification, the manufacturer shall meet all applicable requirements of Section III of the Code. The plate used to fabricate the pipe shall conform to the applicable SA specification in ASME Boiler and Pressure Vessel Code, Section II. The joints shall be full penetration butt welds as obtained by double welding or by other means which will obtain the same quality of deposited and weld metal on the inside and outside. Welds using metal backing strips which remain in place are excluded. The product is subject to all requirements of Section III of the Code including welding, heat treatment, nondestructive examination, authorized inspection at the point of manufacture, and application of the Code Symbol Stamp.

The applicable ASME Partial Data Report Form, signed by an Authorized Inspector, and a certified mill test report shall be furnished for each lot of pipe as defined by requirement S 14 of this specification. Each length of pipe shall be marked in such a manner as to identify each piece with the lot and the certified mill test report.

1. Scope

1.1 This specification covers steel pipe: electric-fusion-welded with filler metal added, fabricated from pressure-vessel quality plate of any of several analyses and strength levels and suitable for high-pressure service at moderate temperatures. Heat treatment may or may not be required to attain the desired properties or to comply with applicable code requirements. Supplementary requirements are provided for use when additional testing or examination is desired.

1.2 The specification nominally covers pipe 16 in. (405 mm) in outside diameter or larger with wall thicknesses up to 3 in. (75 mm), inclusive. Pipe having other dimensions may be furnished provided it complies with all other requirements of this specification.

1.3 Several grades and classes of pipe are provided.

1.3.1 *Grade* designates the type of plate used.

1.3.2 *Class* designates the type of heat treatment performed during manufacture of the pipe, whether the weld is radiographically examined, and whether the pipe has been pressure tested as listed in 1.3.3.

1.3.3 Class designations are as follows (Note 1):

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see Section
10	none	none	none
11	none	9	none
12	none	9	8.3
13	none	none	8.3
20	stress relieved, see 5.3.1	none	none
21	stress relieved, see 5.3.1	9	none
22	stress relieved, see 5.3.1	9	8.3
23	stress relieved, see 5.3.1	none	8.3
30	normalized, see 5.3.2	none	none
31	normalized, see 5.3.2	9	none
32	normalized, see 5.3.2	9	8.3
33	normalized, see 5.3.2	none	8.3
40	normalized and tempered, see 5.3.3	none	none

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see Section
41	normalized and tempered, see 5.3.3	9	none
42	normalized and tempered, see 5.3.3	9	8.3
43	normalized and tempered, see 5.3.3	none	8.3
50	quenched and tempered, see 5.3.4	none	none
51	quenched and tempered, see 5.3.4	9	none
52	quenched and tempered, see 5.3.4	9	8.3
53	quenched and tempered, see 5.3.4	none	8.3

NOTE 1 — Selection of materials should be made with attention to temperature of service. For such guidance, Specification A 20 may be consulted.

1.4 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

2.1.1 *General:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates
A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates
A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications
E 110 Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers
E 165 Practice for Liquid Penetrant Inspection Method
E 350 Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron
E 709 Practice for Magnetic Particle Examination

2.1.2 *Plate Steel Specifications* (Table 1):

A 202/A 202M Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon
A 204/A 204M Pressure Vessel Plates, Alloy Steel, Molybdenum
A 285/A 285M Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
A 299/A 299M Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
A 302/A 302M Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
A 442/A 442M Pressure Vessel Plates, Carbon Steel, Improved Transition Properties
A 515/A 515M Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
A 516/A 516M Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
A 533/A 533M Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
A 537/A 537M Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel

2.2 ASME Boiler and Pressure Vessel Code:
Section II, Material Specifications
Section III, Nuclear Vessels
Section VIII, Unfired Pressure Vessels
Section IX, Welding Qualifications

3. Terminology

3.1 *Description of a Term Specific to This Standard:*

3.1.1 A *lot* shall consist of 200 ft (61 m) or fraction thereof of pipe from the same heat of steel.

3.1.2 The description of a lot may be further restricted by use of Supplementary Requirement S14.

4. Ordering Information

4.1 The inquiry and order for material under this specification should include the following information:

4.1.1 Quantity (feet, meters, or number of lengths),

4.1.2 Name of material (steel pipe, electric-fusion-welded),

4.1.3 Specification number,

4.1.4 Grade and class designations (see 1.3),

4.1.5 Size (inside or outside diameter, nominal or minimum wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish (11.4),

4.1.8 Purchase options, if any (see 5.2.3, 11.3, 14.1 and Sections 16, 20.1, 21, 22 of Specification A 530), and

4.1.9 Supplementary requirements, if any, (refer to S1 through S14).

5. Materials and Manufacture

5.1 *Materials* — The steel plate material shall conform to the requirements of the applicable plate specification for pipe grade ordered as listed in Table 1.

5.2 *Welding:*

5.2.1 The joints shall be double-welded, full-penetration welds made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

5.2.2 The welds shall be made either manually or automatically by an electric process involving the deposition of filler metal.

5.2.3 The welded joint shall have positive reinforcement at the center of each side of the weld, but not more than $\frac{1}{8}$ in. (3.2 mm). This reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be smooth, and the deposited metal shall be fused smoothly and uniformly into the plate surface.

5.2.4 When radiographic examination in accordance with 9.1 is to be used, the weld reinforcement shall be governed by the more restrictive provisions of UW-51 of Section VIII of the ASME Boiler and Pressure Vessel Code instead of 5.2.3 of this specification.

5.3 *Heat Treatment* — All classes other than 10, 11, 12 and 13 shall be heat treated in furnace controlled to ± 25°F (14°C) and equipped with a recording pyrometer so that heating records are available. Heat treating after forming and welding shall be to one of the following:

5.3.1 Classes 20, 21, 22, and 23 pipe shall be uniformly heated within the post-weld heat-treatment temperature range indicated in Table 2 for a minimum of 1 h/in. of thickness or 1 h, whichever is greater.

5.3.2 Classes 30, 31, 32, and 33 pipe shall be uniformly heated to a temperature in the austenitizing range and not exceeding the maximum normalizing temperature indicated in Table 2 and subsequently cooled in air at room temperature.

5.3.3 Classes 40, 41, 42, and 43 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of $\frac{1}{2}$ h/in. of thickness or $\frac{1}{2}$ h, whichever is greater, and air cooled.

5.3.4 Classes 50, 51, 52, and 53 pipe shall be uniformly heated to a temperature in the austenitizing range, and not exceeding the maximum quenching temperature indicated in Table 2 and subsequently quenched in water or oil. After quenching the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of $\frac{1}{2}$ h/in. of thickness or $\frac{1}{2}$ h, whichever is greater, and air cooled.

6. General Requirements for Delivery

6.1 Only the following sections of Specification A 530 shall apply: 1, 2, 7, 8, 14, 16, 17, 19, 20, 21, and 22. Section 6 of A 530 shall apply only for classes requiring Hydrostatic Testing.

7. Chemical Composition

7.1 *Product Analysis of Plate* — The pipe manufacturer shall make an analysis of each mill heat of plate material. The product analysis so determined shall meet the requirements of the plate specification to which the material was ordered.

7.2 *Product Analysis of Weld* — The pipe manufacturer shall make an analysis of the finished deposited weld material from each 500 ft (152 m) or fraction thereof. Analysis shall conform to the welding procedure for deposited weld metal.

7.3 Analysis may be taken from the mechanical test specimens. The results of the analyses shall be reported to the purchaser.

7.4 If the analysis of one of the tests specified in 7.1 or 7.2 does not conform to the requirements specified, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified. Nonconforming pipe shall be rejected.

8. Mechanical Properties

8.1 *Tension Test:*

8.1.1 *Requirements* — Transverse tensile properties of the welded joint shall meet the minimum requirements for ultimate tensile strength of the specified plate material. In addition for Grades Dxx, Hxx, Jxx, and Nxx in Classes 3x, 4x, and 5x transverse tensile properties of the base plate, shall be determined on specimens cut from the heat-treated pipe. These properties shall meet the mechanical test requirements of the plate specification.

8.1.2 *Number of Tests* — One test specimen shall be made to represent each lot of finished pipe.

8.1.3 *Test Specimen Location and Orientation* — The test specimens shall be taken transverse to the weld at the end of the finished pipe and may be flattened cold before final machining to size.

8.1.4 *Test Method* — The test specimen shall be made in accordance with QW-150 in Section IX of the ASME Boiler and Pressure Vessel Code. The test specimen shall be tested at room temperature in accordance with Test Methods and Definitions A 370.

8.2 *Transverse-Guided-Weld-Bend Tests:*

8.2.1 *Requirements* — The bend test shall be acceptable if no cracks or other defects exceeding $\frac{1}{8}$ in. (3.2 mm) in any direction are present in the weld metal or between the weld and the base metal after bending. Cracks that originate along the edges of the specimen during testing, and that are less than $\frac{1}{4}$ in. (6.4 mm) measured in any direction shall not be considered.

8.2.2 *Number of Tests* — One test (two specimens) shall be made to represent each lot of finished pipe.

8.2.3 *Test Specimen Location and Orientation* — Two bend test specimens shall be taken transverse to the weld at the end of the finished pipe. As an alternative by agreement between the purchaser and the manufacturer, the test specimens may be taken from a test plate of the same material as the pipe, the test plate being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

98 **8.2.4** *Test Method* — The test requirements of Test Methods and Definitions A 370, A2.5.1.7 shall be met. For wall thickness over $\frac{3}{8}$ in. (9.5 mm) but less than $\frac{3}{4}$ in. (19.0 mm) side-bend tests may be made instead of the face and root-bend tests. For wall thicknesses $\frac{3}{4}$ in. and over both specimens shall be subjected to the side-bend test.

8.3 *Pressure Test* — Classes X2 and X3 pipe shall be tested in accordance with Specification A 530, Section 6.

9. Radiographic Examination

9.1 The full length of each weld of Classes X1 and X2 shall be radiographically examined in accordance with and meet the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, paragraph UW-51.

9.2 Radiographic examination may be performed prior to heat treatment.

10. Rework

10.1 *Elimination of Surface Imperfections* — Unacceptable surface imperfections shall be removed by grinding or machining. The remaining thickness of the section shall be no less than the minimum specified in Section 11. The depression after grinding or machining shall be blended uniformly into the surrounding surface.

10.2 *Repair of Base Metal Defects by Welding:*

10.2.1 The manufacturer may repair, by welding, base metal where defects have been removed, provided the depth of the repair cavity as prepared for welding does not exceed $\frac{1}{3}$ of the nominal thickness and the requirements of 10.2.2, 10.2.3, 10.2.4, 10.2.5, and 10.2.6 are met. Base metal defects in excess of these may be repaired with proper approval of the customer.

10.2.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair welding.

10.2.3 The welding procedure and welders or welding operators are to be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.2.4 The full length of the repaired pipe shall be heat treated after repair in accordance with the requirements of the pipe class specified.

10.2.5 Each repair weld of a defect where the cavity, prepared for welding, has a depth exceeding the lesser of $\frac{3}{8}$ in. (9.5 mm) or 10% of the nominal thickness shall be examined by radiography in accordance with the methods and the acceptance standards of Section 9.

10.2.6 The repair surface shall be blended uniformly into the surrounding base metal surface and examined and accepted in accordance with Section S6 or S8.

10.3 *Repair of Weld Metal Defects by Welding:*

10.3.1 The manufacturer may repair weld metal defects if he meets the requirements of 10.2.3, 10.2.4, 10.3.2, 10.3.3, and 10.4.

10.3.2 The defects shall be removed by suitable mechanical or thermal cutting or gouging methods and the repair cavity examined and accepted in accordance with Sections S7 or S9.

10.3.3 The weld repair shall be blended uniformly into the surrounding metal surfaces and examined and accepted in accordance with 9.1 and Sections S7 or S9.

10.4 *Retest* — Each length of repaired pipe of a class requiring a pressure test shall be hydrostatically tested following repair.

11. Dimensions, Mass and Permissible Variations

11.1 The wall thickness and weight for welded pipe furnished to this specification shall be governed by the requirements of the specification to which the manufacturer ordered the plate.

11.2 Permissible variations in dimensions at any point in a length of pipe shall not exceed the following:

11.2.1 *Outside Diameter* — Based on circumferential measurement ± 0.5% of the specified outside diameter.

11.2.2 *Out-of-Roundness* — Difference between major and minor outside diameters, 1%.

11.2.3 *Alignment* — Using a 10-ft (3-m) straightedge placed so that both ends are in contact with the pipe, $\frac{1}{8}$ in. (3.2 mm).

11.2.4 *Thickness* — The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. (0.3 mm) under the specified nominal thickness.

11.3 Circumferential welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

11.4 Lengths with unmachined ends shall be within −0, +$\frac{1}{2}$ in. (−0, +13 mm) of that specified. Lengths with machined ends shall be as agreed upon between the manufacturer and the purchaser.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall be free of injurious defects and shall have a workmanlike finish. This requirement is to mean the same as the identical requirement that appears in Specification A 20 with respect to steel plate surface finish.

13. Product Marking

13.1 In addition to the marking provision of Specification A 530, class marking in accordance with 1.3.3 shall follow the grade marking; for example, C 70 — 10.

13.2 *Bar Coding* — In addition to the requirements in 13.1, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

TABLE 1
PLATE SPECIFICATION

Pipe Grade	Type of Steel	ASTM Specification No.	ASTM Specification Grade
A 45	plain carbon	A 285	A
A 50	plain carbon	A 285	B
A 55	plain carbon	A 285	C
B 55	plain carbon, killed	A 515	55
B 60	plain carbon, killed	A 515	60
B 65	plain carbon, killed	A 515	65
B 70	plain carbon, killed	A 515	70
C 55	plain carbon, killed, fine grain	A 516	55
C 60	plain carbon, killed, fine grain	A 516	60
C 65	plain carbon, killed, fine grain	A 516	65
C 70	plain carbon, killed, fine grain	A 516	70
D 70	manganese-silicon-normalized	A 537	1
D 80	manganese-silicon — Q&T[A]	A 537	2
E 55	plain carbon	A 442	55
E 60	plain carbon	A 442	60
H 75	manganese-molybdenum-normalized	A 302	A
H 80	manganese-molybdenum-normalized	A 302	B, C or D
J 80	manganese-molybdenum — Q&T[A]	A 533	Cl-1[B]
J 90	manganese-molybdenum — Q&T[A]	A 533	Cl-2[B]
J 100	manganese-molbydenum — Q&T[A]	A 533	Cl-3[B]
L 65	molybdenum	A 204	A
L 70	molybdenum	A 204	B
L 75	molybdenum	A 204	C
N 75	manganese-silicon	A 299	. . .

[A] Q&T = quenched and tempered.
[B] Any grade may be furnished.

TABLE 2
HEAT TREATMENT PARAMETERS

Pipe Grade[A]	Specification and Grade[B]	Post-Weld Heat-Treat Temperature Range, °F (°C)	Normalizing Temperature, max, °F (°C)	Quenching Temperature, max, °F (°C)	Tempering Temperature, min, °F (°C)
A 45	A 285A	1100–1250 (590–680)	1700 (925)	. . .	. . .
A 50	A 285B	1100–1250 (590–680)	1700 (925)	. . .	. . .
A 55	A 285C	1100–1250 (590–680)	1700 (925)	. . .	. . .
B 55	A 515-55	1100–1250 (590–680)	1700 (950)	. . .	. . .
B 60	A 515-60	1100–1250 (590–680)	1750 (950)	. . .	. . .
B 65	A 515-65	1100–1250 (590–680)	1750 (950)	. . .	. . .
B 70	A 515-70	1100–1250 (590–680)	1750 (950)	. . .	. . .
C 55	A 516-55	1100–1250 (590–680)	1700 (925)	1650 (900)	1200 (650)
C 60	A 516-60	1100–1250 (590–680)	1700 (925)	1650 (900)	1200 (650)
C 65	A 516-65	1100–1250 (590–680)	1700 (925)	1650 (900)	1200 (650)
C 70	A 516-70	1100–1250 (590–680)	1700 (925)	1650 (900)	1200 (650)
D 70	A 537-1	1100–1250 (590–680)	1700 (925)	. . .	. . .
D 80	A 537-2	1100–1250 (590–680)	. . .	1650 (900)	1200 (650)
E 55	A 442-55	1100–1250 (590–680)	1700 (925)	1650 (900)	1200 (650)
E 60	A 442-60	1100–1250 (590–680)	1700 (925)	1650 (900)	1200 (650)
H 75	A 302-A	1100–1250 (590–680)	1800 (980)	. . .	1100 (590)
H 80	A 302-B, C or D	1100–1250 (590–680)	1800 (980)	. . .	1100 (590)
J 80	A 533-C11[B]	1100–1250 (590–680)	. . .	1800 (980)	1100 (590)
J 90	A 533-C12[B]	1100–1250 (590–680)	. . .	1800 (980)	1100 (590)
J 100	A 533-C13[B]	1100–1250 (590–680)	. . .	1800 (980)	1100 (590)
L 65	A 204A	1100–1200 (590–650)	. . .	. . .	. . .
L 70	A 204B	1100–1200 (590–650)	. . .	. . .	. . .
L 75	A 204C	1100–1200 (590–650)	. . .	. . .	. . .
N 75	A 299	1100–1200 (590–650)	1700 (925)	. . .	. . .

[A] Numbers indicate minimum tensile strength in ksi.
[B] Any grade may be used.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Tension and Bend Tests

S1.1 Tension tests in accordance with 8.1 and bend tests in accordance with 8.2 shall be made on specimens representing each length of pipe.

S2. Charpy V-Notch Test (For pipe with nominal wall thickness of ½ in. and greater)

98 **S2.1** *Requirements* — The acceptable test energies shall be as shown in A1.15 of Specification A 20 for the applicable plate specification unless otherwise stated in the order. As an alternative, the test temperature may be 10°F (−12°C).

S2.2 *Number of Specimens* — Each test shall consist of at least three specimens.

98 **S2.2.1** One base-metal test shall be made from one pipe length per heat, per heat-treat charge, and per nominal wall thickness. For pipe from Classes 10, 11, 12, and 13, one base metal test shall be made per heat per size and per wall thickness.

S2.2.2 One weld-metal and one heat-affected zone (HAZ) metal test shall be made in accordance with NB-4335 of Section III of the ASME Boiler and Pressure Vessel Code.

S2.3 *Test Specimen Location and Orientation:*

S2.3.1 Base-metal specimens of stess-relieved, normalized, and normalized and tempered pipe shall be taken in accordance with the provisions for tension specimens in the body of this specification.

S2.3.2 Base-metal specimens of quenched and tempered pipe shall be taken in accordance with the provisions of NB-2225 of Section III of the ASME Boiler and Pressure Vessel Code.

S3. Hardness Test

S3.1 Hardness measurements in accordance with Test Methods and Definitions A 370 or Method E 110 shall be made across the welded joint at both ends of each length of pipe. The maximum acceptable hardness shall be as agreed upon between the manufacturer and the purchaser.

S4. Product Analysis

S4.1 Product analyses in accordance with 7.1 shall be made on each 500 ft (152 m) of pipe or fraction thereof or alternatively, on each length of pipe as designated in the order.

S5. Metallography

S5.1 The manufacturer shall furnish one photomicrograph to show the microstructure of 100× magnification of the weld metal or base metal of the pipe in the as-finished condition. The purchaser shall state in the order: the material, base metal or weld, and the number and locations of tests to be made. This test is for information only.

S6. Magnetic Particle Examination of Base Metal

S6.1 All accessible surfaces of the pipe shall be examined in accordance with Methods E 109 or E 138. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. (610 mm) in diameter and greater, and inside surfaces of pipe less than 24 in. in diameter for a distance of one pipe diameter from the ends.

S6.2 *Acceptance Standards* — The following relevant indications are unacceptable:

S6.2.1 Any linear indications greater than $\frac{1}{16}$ in. (1.6 mm) long for materials less than $\frac{5}{8}$ in. (15.9 mm) thick; greater than $\frac{1}{8}$ in. (3.2 mm) long for materials $\frac{5}{8}$ in. thick to under 2 in. (50.8 mm) thick; and greater than $\frac{3}{16}$ in. (4.8 mm) long for materials 2 in. thick or greater.

S6.2.2 Rounded indications with dimensions greater than $\frac{1}{8}$ in. (3.2 mm) for thicknesses less than $\frac{5}{8}$ in. (15.9 mm) and greater than $\frac{3}{16}$ in. (4.8 mm) for thicknesses $\frac{5}{8}$ in. and greater.

S6.2.3 Four or more indications in any line separated by $\frac{1}{16}$ in. (1.6 mm) or less edge-to-edge.

S6.2.4 Ten or more indications in any 6 in.^{2} (39 cm^2) of surface with the major dimension of this area not to exceed 6 in. (152 mm) when it is taken in the most unfavorable orientation relative to the indications being evaluated.

S7. Magnetic Particle Examination of Weld Metal

S7.1 All accessible weld shall be examined in accordance with Practice E 709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe less than 24 in. (610 mm) in diameter for a distance of one pipe diameter from the ends.

S7.2 *Acceptance Criteria* — The following relevant indications are unacceptable:

S7.2.1 Any cracks and linear indications.

S7.2.2 Rounded indications with dimensions greater than $\frac{3}{16}$ in. (4.8 mm).

S7.2.3 Four or more indications in any line separated $\frac{1}{16}$ in. (1.6 mm) or less edge-to-edge.

S7.2.4 Ten or more indications in any 6 in.^{2} (39 cm^2) of surface with the major dimension of this area not to exceed 6 in. (152 mm) when it is taken in the most unfavorable orientation relative to the indications being evaluated.

S8. Liquid Penetrant Examination of Base Metal

S8.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E 165. Accessible is as defined in S6.1.

S8.2 The acceptance criteria shall be in accordance with S6.2.

S9. Liquid Penetrant Examination of Weld Metal

S9.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E 165. Accessible is as defined in S7.1.

S9.2 The acceptance criteria shall be in accordance with S7.2.

S10. Straight Beam Ultrasonic Examination of Flat Plate — UT 1

S10.1 The plate shall be examined and accepted in accordance with Specification A 435 except that 100% of one surface shall be scanned by moving the search unit in parallel paths with not less than 10% overlap.

S11. Straight Beam Ultrasonic Examination of Flat Plate — UT 2

S11.1 The plate shall be examined in accordance with Specification A 578 except that 100% of one surface shall be scanned and the acceptance criteria shall be as follows:

S11.2 Any area, where one or more discontinuities produce a continuous total loss of back reflection accompanied by continuous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. (76.2 mm) or $\frac{1}{2}$ of the plate thickness, whichever is greater, is unacceptable. In addition, two or more discontinuities on the same plane and having the same characteristics but smaller than described above shall be unacceptable unless separated by a minimum distance equal to the largest diameter of the larger discontinuity or unless they may be collectively encompassed by the circle described above.

S12. Angle-Beam Ultrasonic Examination (Plate Less than 2 in. (50.8 mm) Thick) — UT 3

S12.1 The plate shall be examined in accordance with Specification A 577 except that the calibration notch shall be V-shaped and the acceptance criteria shall be as follows: Any area showing one or more reflectors producing indications whose amplitude exceeds that of the calibration notch is unacceptable.

S13. Repair Welding

S13.1 Repair of base metal defects by welding shall be done only with customer approval.

S14. Description of Term

S14.1 *lot* — all pipe of the same mill heat of plate material and wall thickness (within $\pm 1/4$ in. (6.4 mm)) heat treated in one furnace charge. For pipe that is not heat treated or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft (61 m) or fraction thereof of all pipe of the same mill heat of plate material and wall thickness (within $\pm 1/4$ in. (6.4 mm)), subjected to the same heat treatment. For pipe heat treated in a batch-type furnace that is automatically controlled within a 50°F (28°C) range and is equipped with recording pyrometers so that heating records are available, a lot shall be defined the same as for continuous furnaces.

SPECIFICATION FOR STEEL BARS, CARBON, HOT-WROUGHT, SPECIAL QUALITY, MECHANICAL PROPERTIES

SA-675/SA-675M

[Identical with ASTM Specification A 675/A 675M-90a (Reapproved 1995)$^{\epsilon 1}$] 98

1. Scope

1.1 This specification covers hot-wrought special quality carbon steel bars and bar size shapes produced to mechanical property requirements and intended for general constructional applications.

1.2 The bars are available in nine strength grades designated 45, 50, 55, 60, 65, 70, 75, 80, and 90 [310, 345, 380, 415, 450, 485, 515, 550, and 620] corresponding to the minimum ultimate tensile strength in ksi [MPa]. The chemical composition is selected by the manufacturer to develop the required mechanical properties.

1.3 Hot-wrought special quality carbon steel bars subject to mechanical property requirements are hot wrought in straight lengths only. Sections and sizes available are covered in Specification A 29/A 29M.

1.4 Some applications may require one or more of the available designations shown under Supplementary Requirements.

NOTE 1 — Merchant-quality hot-wrought carbon steel bars subject to mechanical property requirements are covered in Specification A 663/A 663M.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not equivalents, therefore each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 663/A 663M Specification for Steel Bars, Carbon, Merchant Quality, Mechanical Properties

E 290 Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials

3. Terminology

3.1 *Description of Term:*

3.1.1 *special quality* — Special quality bars are used when end use, method of fabrication, or subsequent processing treatment requires quality characteristics not available in merchant quality. Typical applications involve bending or machining for general constructional uses. Some end uses or fabricating procedures can necessitate one or more requirements which are described in the Supplementary Requirements.

4. Ordering Information

4.1 Orders for material under this specification should include the following information:

4.1.1 Quantity (weight or number of pieces),

4.1.2 Name of material (hot-wrought special quality bars),

4.1.3 Dimensions, including length,

4.1.4 Cross section (round, square, hexagon, equal leg angle, etc.)

4.1.5 Specification designation and date of issue,

4.1.6 Grade designation (Table 2),

4.1.7 Leaded steel, if required (7.2),

4.1.8 Copper bearing steel, if required (7.3),

4.1.9 Test report, if required (Section 10),

4.1.10 Supplementary Requirements or special requirements if required, and

4.1.11 Application and processing.

NOTE 2 — A typical ordering description is as follows: 10 000 lb, [5000 kg] Hot Wrought Special Quality Carbon Steel Bars, 1 in. diameter × 10 ft, [25 m × 3 m] Round, ASTM A 675/A 675M dated _____, Grade 50, [345] Copper Bearing, Test Report Required, S3 Special Straightness, Boiler Supports.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements for the current edition of Specification A 29/A 29M.

6. Materials and Manufacture

6.1 *Melting Practice* — The steel shall be made by one or more of the following primary processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting using electroslag remelting or vacuum-arc remelting. Where secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

6.2 *Deoxidation:*

6.2.1 Unless otherwise specified, the steel shall be rimmed, capped, semi-killed, or killed at the producer's option.

6.2.2 When required, the purchaser may specify the required deoxidation practice, dependent upon strength grade specified, purchaser's methods of fabrication, and end use requirements. Killed steels can be produced to coarse or fine austenitic grain size (Supplementary Requirement S1).

6.3 *Condition* — Unless otherwise specified, the bars shall be furnished as-rolled and not pickled, blast cleaned, or oiled. At the producer's option, bars may be cleaned for inspection.

7. Chemical Composition

7.1 The steel shall conform to the chemical requirements specified in Table 1.

7.2 *Leaded Steel* — When required, lead may be specified as an added element. When lead is specified as an added element, a range from 0.15 to 0.35% inclusive shall be furnished. Such a steel is identified by adding the letter L after the grade designation, for example 60L [415L].

7.3 *Copper-Bearing Steel* — When required copper may be specified as an added element. Copper-bearing steel is identified by stating "copper-bearing" on the purchase order.

7.4 When tension tests are waived in accordance with 8.1.1.2, chemistry consistent with the mechanical properties desired shall be applied.

8. Mechanical Properties

8.1 *Tension Tests*

8.1.1 *Requirements:*

8.1.1.1 The material as represented by the test specimen shall conform to the applicable requirements in Table 2.

8.1.1.2 Shapes less than 1 in.^{2} [645 mm^2] in cross section and bars (other than flats) less than $\frac{1}{2}$ in. [12.5 mm] in thickness or diameter need not be subject to tension tests by the manufacturer.

8.1.1.3 For material over $\frac{3}{4}$ in. [19 mm] in thickness or diameter, a deduction of 0.25% from the percentage of elongation in 8 in. [200 mm] specified in Table 2 shall be made for each increase of $\frac{1}{32}$ in. [0.8 mm] in the specified thickness or diameter above $\frac{3}{4}$ in. [19 mm].

8.1.1.4 For material under $\frac{5}{16}$ in. [8 mm] in thickness or diameter, a deduction of 2.00% from the percentage of elongation in 8 in. [200 mm] specified in Table 2 shall be made for each decrease of $\frac{1}{32}$ in. [0.8 mm] in the specified thickness or diameter below $\frac{5}{16}$ in. [8 mm].

8.1.1.5 For Grades 45, 50, 55, 60, and 65 [310, 345, 380, and 415] for material over 2 in. [50 mm] in thickness or diameter, a deduction of 1.00% from the percentage of elongation in 2 in. [50 mm] specified in Table 2 shall be made for each 1 in. [25 mm] of specified thickness or diameter or fraction thereof over 2 in. [50 mm] in thickness or diameter.

8.1.1.6 For Grades 70, 75, 80, and 90 [485, 515, 550, and 620] for material over 2 in. [50 mm] in thickness or diameter, a deduction of 1.00% from the percentage of elongation in 2 in. [50 mm] specified in Table 2 shall be made for each 1 in. [25 mm] of specified thickness or diameter, or fraction thereof, over 2 in. [50 mm] in diameter or thickness, to a maximum deduction of 3%.

8.1.2 *Test Specimens:*

8.1.2.1 Test specimens shall be prepared for testing from the material in its as-rolled condition unless otherwise specified (see Supplementary Requirements). The tension specimen may be aged as described in Test Methods and Definitions A 370.

8.1.2.2 Test specimens shall be taken longitudinally and may be tested in full thickness or section, or they may be machined to the dimensions shown in Figs. 4 or 5 of Test Methods and Definitions A 370. If test specimens are selected conforming to the dimensions of Fig. 5, they shall be machined from a position midway between the center and the surface of the bar.

8.1.2.3 Test specimens for shapes and flats may be machined to the form and dimensions shown in Fig. 4 of Test Methods and Definitions A 370 or with both edges parallel. Test specimens for material over 1½ in. [40 mm] in thickness or diameter may be machined to a thickness or diameter of at least ¾ in. [20 mm] for a length of at least 9 in. [230 mm], or they may conform to the dimensions shown in Fig. 5 of Test Methods and Definitions A 370.

8.1.3 *Number of Tests* — Two tension tests shall be made from each heat, unless the finished material from a heat is less than 50 tons [45 Mg], when one tension test will be sufficient. However, for material 2 in. [50 mm] and under in thickness, when the material from one heat differs ⅜ in. [9.5 mm] or more in thickness, one tension test shall be made from both the thickest and the thinnest material rolled (larger than the sizes in 8.1.1.2) regardless of the weight represented. For material over 2 in. [50 mm] thick, when the material from heat differs 1 in. [25 mm] or more in thickness, one tension test shall be made from both the thickest and the thinnest material rolled that is more than 2 in. [50 mm] thick regardless of the weight represented.

8.1.4 *Test Method* — Tension tests shall be made in accordance with Test Methods and Definitions A 370 using the applicable method for determining yield point.

8.2 *Bend Tests:*

8.2.1 *Requirements:*

8.2.1.1 Bend requirements apply only to flat bars (all sizes), bars other than flats less than ½ in. [12.5 mm] in thickness or diameter, and shapes less than 1 $in.^2$ [645 mm^2] in cross section. When bend tests are required for other sizes, Supplementary Requirement S6 must be specified.

8.2.1.2 The bend test specimen shall stand being bent at room temperature through 180° without cracking on the outside of the bent portion, to an inside diameter which shall have the relation to the thickness or diameter of the specimen as given in Table 3.

8.2.2 *Test Specimens:*

8.2.2.1 Bend test specimens for material 1½ in. [40 mm] and under in diameter or thickness may be the full thickness of the section. For flat bars over 2 in. [50 mm] in width, the width may be reduced by milling to 1½ in. [40 mm].

8.2.2.2 Bend test specimens for material over 1½ in. [40 mm] in diameter or thickness may be machined to a thickness or diameter of at least ¾ in. [20 mm] or to 1 by ½ in. [25 by 12.5 mm] in section. Machined sides of bend test specimens may have the corners rounded to a radius of not over 1/16 in. [1.6 mm] for material 2 in. [50 mm] and under in thickness, and not over ⅛ in. [3.2 mm] in radius for material over 2 in. [50 mm] in thickness.

8.2.3 *Number of Tests* — When subject to bend test, two bend tests shall be made from each heat, unless the finished material from a heat is less than 50 tons [45 Mg], when one bend test will be sufficient. However, for material 2 in. [50 mm] and under in thickness, when the material from one heat differs ⅜ in. [9.5 mm] or more in thickness, one bend test shall be made from both the thickest and the thinnest material rolled regardless of the weight represented. For material over 2 in. [50 mm] thick, when the material from one heat differs 1 in. [25 mm] or more in thickness, one bend test shall be made from both the thickest and the thinnest material rolled that is more than 2 in. [50 mm] thick regardless of the weight represented.

8.2.4 *Test Methods* — Bend tests shall be made in accordance with Test Method E 290.

9. Workmanship, Finish, and Appearance

9.1 Bars shall be free of visible pipe, undue segregation, and injurious surface imperfections.

9.2 *Surface Finish* — The bars shall have a commercial hot-wrought finish obtained by conventional hot rolling. See 6.3 for producer's descaling option.

10. Certification

10.1 When specified by the purchaser, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the heat analysis, tensile requirements, and bend test (if applicable) test results shall be furnished. Only one test need by reported when the amount of material from a heat in a shipment is less than 10 tons [9 Mg] and when the thickness variations described in 8.1.3 and 8.2.3 are not exceeded. The report shall include the name of the manufacturer, ASTM designation number and year date and revision letter, if any, grade, heat number, and size.

10.2 The thickness of the product tested may not necessarily be the same as an individual ordered thickness since it is the heat that is tested rather than each ordered item.

10.3 When Supplementary Requirements are specified, the report shall include a statement of compliance with the requirement or the results of tests when the requirement involves measured test values.

11. Keywords

11.1 carbon steel bars; hot-wrought steel bars; steel bars

TABLE 1
CHEMICAL REQUIREMENTS (HEAT ANALYSIS)

Element	
Phosphorus, max	0.040
Sulfur, max	0.050
Copper, when copper steel is specified, min	0.20
Lead	[A]

[A] When required, lead may be specified as an added element. See 7.2.

TABLE 2
TENSILE REQUIREMENTS

Grade Designation[B]	Tensile Strength		Yield Point, min[A]		Elongation, min, %[C]	
	ksi	[MPa]	ksi	[MPa]	8 in. or [200 mm] Gage Length	2 in. or [50 mm] Gage Length
45 [310]	45 to 55	[310 to 380]	22.5	[155]	27	33
50 [345]	50 to 60	[345 to 415]	25	[170]	25	30
56 [380]	55 to 65	[380 to 450]	27.5	[190]	23	26
60 [415]	60 to 72	[415 to 495]	30	[205]	21	22
65 [450]	65 to 77	[450 to 530]	32.5	[225]	17	20
70 [485]	70 to 85	[485 to 585]	35	[240]	14	18
75 [515]	75 to 90	[515 to 620]	37.5	[260]	14	18
80 [550]	80 min	[550 min]	40	[275]	13	17
90 [620]	90 min	[620 min]	55	[380]	10	14

[A] When the tension test does not show a yield point (drop of the beam, halt of the pointer or sharp-kneed stress-strain diagram), yield strength shall be determined by either 0.5% extension-under-load or 0.2% offset. The minimum ksi (MPa) requirement does not change. The test report, if required, shall show yield strength.
[B] When lead is required, add the letter "L" after the grade designation, for example 45L.
[C] See 8.1.1.3 through 8.1.1.6 for deduction in elongation due to section size.

TABLE 3
BEND REQUIREMENTS

Grade Designation	Ratio of Bend Diameter to Thickness of Specimen for Thickness or Diameter of Bar, in. (mm)						
	3/4 [20] and Under	Over 3/4 [20] to 1 [25], incl	Over 1 [25] to 1 1/2 [40], incl	Over 1/2 [40] to 2 [50], incl	Over 2 [50] to 3 [75], incl	Over 3 [75] to 5 [125], incl	Over 5 [125]
45 [310]	flat	flat	1/2	1	1	2	3
50 [345]	flat	1/2	1	1 1/2	2 1/2	3	3 1/2
55 [380]	1/2	1	1 1/2	3	2 1/2	3	3 1/2
60 [415]	1/2	1	1 1/2	2 1/2	3	3 1/2	4
65 [450]	1	1 1/2	2	3	3 1/2	4	5
70 [485]	1 1/2	2	2 1/2	3	3 1/2	4	5
75 [515]	2	2	3	3 1/2	4	4 1/2	6
80 [550]	2	2 1/2	3	3 1/2	4	4 1/2	6
90 [620][A]							

[A] Bend requirements are not required for Grade 90 [620], but may be specified by agreement between purchaser and manufacturer (see Supplementary Requirement S6).

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirements of the specification itself.

S1. Grain Size

S1.1. The steel shall conform to the coarse austenitic grain size requirement, or the fine austenitic grain size requirement of Specification A 29/A 29M.

S2. Thermal Treatment

S2.1 When required, the purchaser may specify that the material be stress relieved.

S3. Special Straightness

S3.1 Bars may be specified to special straightness tolerance (refer to Specification A 29/A 29M).

S4. Cleaning

S4.1 The purchaser may specify that the surface of bars be descaled by pickling or blast cleaning.

S5. Coating

S5.1 The purchaser may specify oil on bars that have been descaled.

S6. Bend Requirement

S6.1 Bend requirements for Grade 90 [620] may be specified. The bend ratio shall be as agreed upon. Bend requirements for all other grades, when specified, shall be as specified in Table 3.

SPECIFICATION FOR WELDED AUSTENITIC STAINLESS STEEL FEEDWATER HEATER TUBES

SA-688/SA-688M

(Identical with ASTM Specification A 688/A 688M-96.)

1. Scope

1.1 This specification covers welded austenitic stainless steel feedwater heater tubes including those bent, if specified, into the form of U-tubes for application in tubular feedwater heaters.

1.2 The tubing sizes covered shall be $\frac{5}{8}$ to 1 in. [15.9 to 25.4 mm] inclusive outside diameter, and average or minimum wall thicknesses of 0.028 in. [0.7 mm] and heavier.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

E 527 Practice for Numbering Metals and Alloys (UNS)

3. General Requirements

3.1 Material furnished to this specification shall conform to the applicable requirements of the latest published edition of Specification A 450/A 450M unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material to this specification should include the following, as required, to adequately describe the desired material:

4.1.1 Quantity (length or number of pieces),

4.1.2 Material description,

4.1.3 Dimensions — Outside diameter, wall thickness (minimum or average wall), and length,

4.1.4 Grade (chemical composition) (Table 1),

4.1.5 U-bend requirements, if order specifies bending, U-bend schedules or drawings shall accompany the order,

4.1.6 Optional requirements — Purchaser shall specify if annealing of the U-bends is required or whether tubes are to be hydrotested or air tested (see 10.6)

4.1.7 Supplementary requirements — Purchaser shall specify on the purchase order if material is to be eddy current tested in accordance with Supplementary Requirement S1 or S2, and if special test reports are required under Supplementary Requirements S3.

5. Materials and Manufacture

5.1 The tube shall be made from flat-rolled steel by an automatic welding process with no addition of filler metal.

5.2 Subsequent to welding and prior to final heat treatment, the tubes shall be cold worked either in both the weld and base metal, or in the weld metal only. The method of cold work may be specified by the purchaser. When cold drawn, the purchaser may specify the minimum amount of reduction in cross-sectional area or wall thickness, or both.

5.3 Many surface contaminants may have detrimental effects on high temperature properties or corrosion resistance of tubing. Contamination by copper, lead, mercury, zinc, chlorides, or sulfur may be detrimental to stainless steels. The manufacturer shall employ techniques that minimize surface contamination by the elements.

6. Cleaning Before Annealing

6.1 All lubricants of coatings used in the manufacture of straight-length tube or in the bending shall be removed from all surfaces prior to any annealing treatments. U-bends on which a lubricant had been applied to the inside surface during bending shall have the cleanness of their inside surface confirmed by blowing close fitting acetone-soaked felt plugs through 10% of the tubes of each bend radius. Dry, oil-free air or inert gas shall be used to blow the plugs through the tubes. If the plugs blown through any tube shows more than a light gray discoloration, all tubes that have had a lubricant applied to the inside surface during bending shall be recleaned. After recleaning 10% of the tubes of each bend radius whose inside surface has been subjected to bending lubricants shall be retested.

7. Heat Treatment

7.1 All finished straight tubing or straight tubing ready for U-bending shall be furnished in the solution-annealed condition except for N08367. The annealing procedure, except for N08926, shall consist of heating the material to a minimum temperature of 1900°F [1040°C] followed by a rapid cooling to below 700°F [370°C]. The cooling rate shall be sufficiently rapid to prevent harmful carbide precipitation as determined in Section 12. UNS N08367 should be solution annealed from 2025°F minimum followed by rapid quenching.

7.2 N08926 shall be heat-treated to a minimum temperature of 2010°F [1100°C] followed by quenching in water or rapidly cooling by other means.

7.3 If heat treatment of U-bends is specified, it shall satisfy the annealing procedure described in 7.1 and 7.2, and shall be done as follows:

7.3.1 The heat treatment shall be applied to the U-bend area plus approximately 6 in. [150 mm] of each leg beyond the tangent point of the U-bend.

7.3.2 If the heat treatment specified in 7.3 is accomplished by resistance-heating methods wherein electrodes are clamped to the tubes, the clamped areas shall be visually examined for arc burns. Burn indications shall be cause for rejection unless they can be removed by local polishing without encroaching upon minimum wall thickness.

7.3.3 Temperature control shall be accomplished through the use of optical or emission pyrometers, or both. No temperature-indicating crayons, lacquers, or pellets shall be used.

7.3.4 The inside of the tube shall be purged with a protective or an inert gas atmosphere during heating and cooling to below 700°F [370°C] to prevent scaling of the inside surface. The atmosphere should be noncarburizing.

8. Surface Condition

8.1 The straight tubes, after final annealing, shall be pickled using a solution of nitric and hydrofluoric acids followed by flushing and rinsing in water. If bright annealing is performed, this requirement does not apply.

8.2 A light oxide scale on the outside surface of U-bend area shall be permitted for tubes which have been electric-resistance heat treated after bending.

9. Chemical Composition

9.1 *Product Analysis*

9.1.1 When requested in the purchase order, a product analysis shall be made by the supplier from one tube or coil of steel per heat. The chemical composition shall conform to the requirements shown in Table 1.

9.1.2 A product analysis tolerance of Specification A 480/A 480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04% or less.

9.1.3 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of this specification; otherwise all remaining material in the heat or lot (Note 1) shall be rejected, or at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of this specification shall be rejected.

NOTE 1 — For flattening and flange requirements, the term "lot" applies to 120 tube groupings, prior to cutting to length, of the same nominal size and wall thickness, produced from the same heat of steel and annealed in a continuous furnace.

10. Mechanical Requirements

10.1 *Tensile Properties:*

10.1.1 The material shall conform to the tensile properties shown in Table 2.

10.1.2 One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 2).

10.2 *Hardness:*

10.2.1 Grade TP XM-29 tubes shall have a hardness number not exceeding 100 HRB or its equivalent. Tubes of all other grades shall have a hardness number not exceeding 90 HRB or its equivalent. This hardness requirement is not to apply to the bend area of U-bend tubes which are not heat treated after bending.

10.2.2 Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot.

NOTE 2 — For tension, hardness, and corrosion test requirements, the term "lot" applies to all tubes prior to cutting to length, of the same nominal diameter and wall thickness, produced from the same heat of steel and annealed in a continuous furnace at the same temperature, time at heat, and furnace speed.

10.3 *Reverse Bend Test:*

10.3.1 One reverse bend test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

10.3.2 A section 4 in. [100 mm] in length shall split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a diameter four times the wall thickness, with the mandrel parallel to the weld and in contact with the outside surface of the tube. The weld shall be at the point of maximum bend. There shall be no evidence of cracks or lack of penetration in the weld or of overlaps resulting from flash removal of the weld.

NOTE 3 — The reverse bend test is not applicable when specified wall is 10% or more of the specified outside diameter, or the wall thickness is 0.134 in. [3.4 mm] or greater, or the outside diameter size is less than 0.375 in. [9.5 mm]. Under these conditions, the reverse flattening test of Specification A 450/A 450M shall apply.

10.4 *Flattening Test* — Flattening tests shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot (Note 1).

10.5 *Flange Test* — Flange tests shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

10.6 *Pressure Test:*

10.6.1 Each straight tube or each U-tube after completion of the bending and post-bending heat treatment, shall be pressure tested in accordance with one of the following paragraphs as specified by the purchaser.

10.6.1.1 *Hydrostatic Test* — Each tube shall be given an internal hydrostatic test in accordance with Specification A 450/A 450M, except that the test pressure and hold time, when other than that stated in Specification A 450/A 450M, shall be agreed upon between purchaser and manufacturer.

10.6.1.2 *Air Underwater Test* — Each tube shall be air underwater tested in accordance with Specification A 450/A 450M.

11. Nondestructive Test (Electric Test)

11.1 Each straight tube shall be tested after the finish heat treatment by passing it through a nondestructive tester capable of detecting defects on the entire cross section of the tube, in accordance with Specification A 450/A 450M.

12. Corrosion Resisting Properties

12.1 One full section sample 1 in. [25.4 mm] long from the center of a sample tube of the smallest radius bend which is heat treated shall be tested in the heat treated condition in accordance with Practices A 262.

12.2 One full-section sample 1 in. [25.4 mm] long from each lot (Note 2) of straight tubes shall be tested in the finished condition in accordance with Practices A 262.

12.3 The appearance of any fissures or cracks in the test specimen when evaluated in accordance with Practices A 262 indicating the presence of intergranular attack, shall be cause for rejection of that lot.

13. Permissible Variations in Dimensions (Fig. 1)

13.1 Permissible variations from the specified outside diameter shall be in accordance with Specification A 450/A 450M. Those tolerances do not apply to the bent portion of the U-tubes. At the bent portion of a U-tube for $R = 2 \times D$ or greater, neither the major nor minor diameter of the tube shall deviate from the nominal diameter prior to bending by more than 10%. If less than $2 \times D$ is specified, tolerances could be greater.

13.2 *Permissible Variations from the Specified Wall Thickness:*

13.2.1 Permissible variations from the specified minimum wall thickness shall not exceed +20% −0.

13.2.2 Permissible variations from the specified average wall thickness are ±10% of the nominal wall thickness.

13.2.3 The wall thickness of the tube in the U-bent section shall not be less than value determined by the equation:

$$t_f = \frac{4RT}{4R + D}$$

where:

t_f = wall thickness after bending, in. [mm],
T = minimum wall thickness of 13.2.1 or 13.2.2, in. [mm],
R = centerline bend radius, in. [mm], and
D = nominal outside tube diameter, in. [mm].

13.3 *Permissible Variations from the Specified Length:*

13.3.1 *Straight Lengths* — The maximum permissible variations for lengths 24 ft [7.3 m] and shorter shall be +1/8 in. [3 mm], −0; for lengths longer than 24 ft [7.3 mm], an additional over tolerance of +1/8 in. [3 mm] for each 10 ft [3 m], or fraction thereof, shall be permitted up to a maximum of +1/2 in. [13 mm].

13.3.2 *U-Bends* — In the case of U-tubes, the length of the tube legs as measured from the point of tangency of the bend and the tube leg to the end of the tube leg, shall not be less than specified, but may exceed the specified values by the amount given in Table 3. The difference in lengths of the tube legs shall not be greater than 1/8 in. unless otherwise specified.

13.4 The end of any tube may depart from square by not more than the amount given in Table 4.

13.5 The leg spacing measured between the points of tangency of the bend to the legs shall not vary from the value ($2R$ − specified tube outside diameter) by more than 1/16 in. [1.5 mm] where R is the center-line bend radius.

13.6 The bent portion of the U-tube shall be substantially uniform in curvature, and not to exceed ±1/16 in. [1.5 mm] of the nominal center-line radius.

13.7 Permissible deviation from the plane of bend (Fig. 1) shall not exceed 1/16 in. [1.5 mm] as measured from the points of tangency.

14. Workmanship, Finish, and Appearance

14.1 Tubing purchased to this specification is intended for use in heat exchangers, and will be inserted through close-fitting holes in baffles or support plates, or both, spaced along the tube length. The tube ends will also be inserted into very close-fitting holes in a tubesheet and expanded and may be welded therein. The tubes shall be able to stand expanding and bending without showing cracks and flaws, and shall be finished reasonably straight and suitable for the intended purpose.

14.2 The residual chloride salt contamination of the inside and outside surface of the tubing at the time of packing for shipment from the mill shall not exceed a concentration of 1 mg/ft^2 [10.7 mg/m^2] of tube surface. One tube in each five hundred pieces shall be checked immediately prior to packing for shipment for chloride salt contamination by a procedure agreed upon by the manufacturer and purchaser.

15. Inspection

15.1 The inspector representing the purchaser shall have entry, at all times, to those areas where inspection and testing is being performed on the purchaser's ordered material. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

16. Rejection

16.1 Each length of tubing received from the manufacturer may be inspected by the purchaser, and if it does

not meet the requirements of the specification based on the inspection and test method outlined in the specification, the tubing may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

16.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective, shall be set aside, and the manufacturer shall be notified. Disposition of such material shall be a matter for agreement between the manufacturer and the purchaser.

17. Certification

17.1 A test report, signed by an authorized employee or representative of the manufacturer, shall be furnished to the purchaser to indicate the specification and grade, the results of the heat analysis, hardness and tensile properties. Product analysis will be reported only when requested on the purchase order as provided in 9.2.1.

18. Product Marking

18.1 All tubes shall be marked with the heat number.

18.2 Containers and packages shall be marked or tagged to show the purchaser's order number, the manufacturer's order number, specification, grade, size and gage of tubing, number of pieces contained in the package, and item number (if appropriate).

19. Packaging

19.1 All tubing shall be packaged and blocked in such a manner as to prevent damage in ordinary handling and transportation. The boxes shall be constructed in such a manner that no nails, staples, screw, or similar fasteners are required to close and secure the box after the tubes have been placed in the box. The box shall be lined with plastic sheet or vapor barrier materials so as to prevent chloride contamination of the tube during handling, transportation, and storage.

19.2 The U-bent tube shall be arranged in boxes so that the smaller radius bends may be removed without disturbing larger radius bends. Tubes for an item number shall be boxed together.

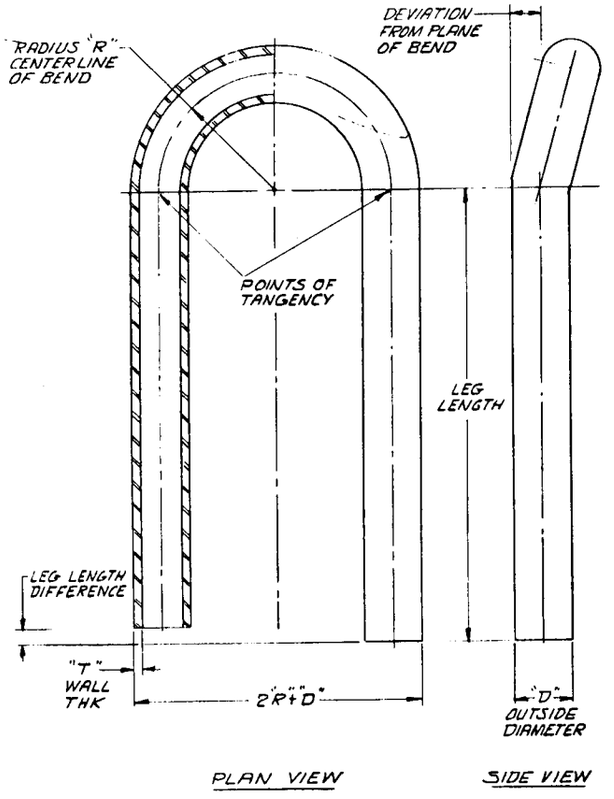


FIG. 1 PLANE BEND FOR U-TUBE

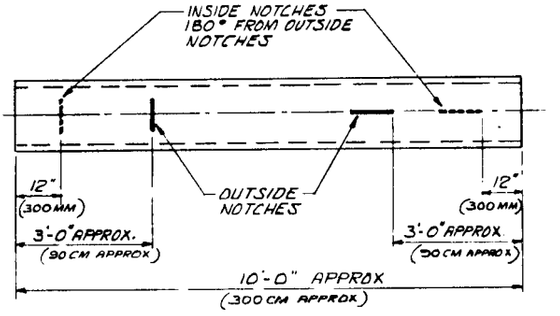


FIG. 2 EDDY-CURRENT TEST STANDARD

TABLE 1
CHEMICAL REQUIREMENTS

Element	Grade	TP 304	TP 304L	TP 304LN	TP 316	TP 316L	TP 316LN	TP XM-29	TP 304N	TP 316N	. . .	. . .
	UNS Designation[A]	S30400	S30403	S30453	S31600	S31603	S31653	S28300	S30451	S31651	N08367	N08926
		Composition, %										
Carbon, max		0.08	0.035	0.035	0.08	0.035	0.035	0.060	0.08	0.08	0.030	0.020
Manganese, max[B]		2.00	2.00	2.00	2.00	2.00	2.00	11.50–14.50	2.00	2.00	2.00	2.00
Phosphorus, max		0.040	0.040	0.040	0.040	0.040	0.040	0.060	0.040	0.040	0.040	0.03
Sulfur, max		0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.01
Silicon, max		0.75	0.75	0.75	0.75	0.75	0.75	1.00	0.75	0.75	1.00	0.5
Nickel		8.00–11.00	8.00–13.00	8.00–13.00	10.00–14.00	10.00–15.00	10.00–15.00	2.25–3.75	8.00–11.0	10.00–14.00	23.50–25.50	24.00–26.00
Chromium		18.00–20.00	18.00–20.00	18.00–20.00	16.00–18.00	16.00–18.00	16.00–18.00	17.00–19.00	18.0–20.0	16.0–18.0	20.00–22.00	19.00–21.00
Molybdenum		. . .	. . .	. . .	2.00–3.00	2.00–3.00	2.00–3.00	. . .	. . .	2.00–3.00	6.00–7.00	6.0–7.0
Nitrogen[C]		. . .	. . .	0.10–0.16	. . .	. . .	0.10–0.16	0.20–0.40	0.10–0.16	0.10–0.16	0.18–0.25	0.15–0.25
Copper		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.75 max	0.5–1.5

[A] New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).
[B] Maximum, unless otherwise noted.
[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

TABLE 2
TENSILE REQUIREMENTS

Grade	304, 316	304L, 316L	XM-29	304N, 316N	304LN, 316LN	. . .	. . .	. . .
UNS Designation	S30400, S31600	S30403, S31603	S28300	S30451, S31651	S30453, S31653	N08367 t ≤ 0.187	N08367 t > 0.187	N08926
Tensile strength, min ksi [MPa]	75 [515]	70 [485]	100 [690]	80 [550]	75 [515]	100 [690]	95 [655]	94 [650]
Yield strength, min ksi [MPa]	30 [205]	25 [175]	55 [380]	35 [240]	30 [205]	45 [310]	45 [310]	43 [295]
Elongation in 2 in. or 50 mm, min, %	35	35	35	35	35	30	30	35

TABLE 3
TUBE LEG LENGTH TOLERANCE

Leg Length, ft [m]	Plus Tolerance, in. [mm]
Up to 20 [6], incl	1/8 [3.2]
Over 20 to 30 [6 to 9], incl	5/32 [4.0]
Over 30 to 40 [9 to 12.2], incl	3/16 [4.8]

TABLE 4
SQUARENESS OF ENDS TOLERANCE

Tube OD, in. [mm]	Tolerance, in. [mm]
5/8 [15.9], incl	0.010 [0.25]
Over 5/8 to 1 in. [15.9 to 25.4], incl	0.016 [0.4]

TABLE 5
NOTCH DEPTH

OD, in. [mm]	Wall, in. [mm]	Depth[A], in. [mm]	Length, max, in. [mm]	Width, max
5/8 to 1 [15.9 to 25.4], incl	0.028 [0.7] and heavier	0.0045 [0.11] or 10% of wall thickness, whichever is greater	0.375 [9.5]	wall thickness but not greater than 0.062 in. [1.6 mm]

[A] The tolerance of notch depth shall be ±8% or ±0.0005 in. [0.01 mm], whichever is greater. Refer to Fig. 2 for notch location orientation and length of calibration standard.

TABLE 6
NOTCH DEPTH FOR SELECT COMMERCIAL GRADE

OD, in. [mm]	Wall, in. [mm]	Depth, in. [mm]	Length, max, in. [mm]	Width, max
5/8 to 1 [15.9 to 25.4], incl	0.035 [0.9] and heavier	0.0045 [0.11] or 10% of wall thickness, whichever is greater	0.375 [9.5]	3 times notch depth
5/8 to 1 [15.9 to 25.4], incl	less than 0.035 [0.9]	0.0045 [0.11] or 10% of wall thickness, whichever is greater	0.375 [9.5]	wall thickness

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement or requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order, in which event the necessary tests shall be made by the manufacturer prior to the bending or shipment of the tubing.

S1. Nondestructive Eddy-Current Test

S1.1 Each tube in the finished condition, except for bending if that is required, shall be tested by passing it through an electric nondestructive tester capable of detecting defects on the entire cross section of the tube. Suitable instrumentation shall be used to clearly distinguish the artificial defects. The outside and inside surfaces of the tubes shall be free of loose scale, metallic particles, or other material which would tend to restrict signals or create electrical noise. The tubing shall be inspected by feeding it longitudinally through an inspection coil or coils with a diameter suitable for the diameter of tubing to be inspected. The instrument calibration shall be accomplished with a reference standard prepared from an appropriate length of selected tubing of the same size, grade, and physical condition as the material to be inspected. The standard shall be fed through the coil at the same speed at which the inspection of the tubing is performed.

S1.2 The factors listed in S1.3 shall be selected or adjusted, or both, in accordance with the instrument manufacturer's instructions, for the particular instrument involved as required to achieve optimum instrument distinction between the reference defects and plain portions of the tube.

S1.3 The following as well as other factors involved shall not be used in such a manner that they detract from the overall ability of the instrument to detect defects: test frequency, direct-current saturation level, filter networks, phase-analysis circuits, coil diameter, and instrument gain.

S1.4 The reference standard shall consists of a defect-free sample of the same size, alloy, and condition (temper) as that being tested, and shall contain longitudinal and circumferential notches on the outside diameter establishing the rejection level of the tubing to be tested. Inside diameter notches, both longitudinal and transverse, shall also be a part of the reference standard. These inside notches may be larger than the outside notches, and are intended for use only to assure instrument phase settings capable of yielding optimum inside surface sensitivity.

S1.4.1 All notches shall be produced by EDM methods. The outside diameter notches shall be of the dimensions shown in Table 5.

S1.5 All tubing shall meet this specification. The instrument calibration shall be verified at the start of testing, after any shut down of the test equipment, after any test equipment adjustment, or at least every $\frac{1}{2}$ h of continuous production testing or both. Tubes generating a signal above the outside diameter calibration standard sensitivity level shall be rejected.

S1.6 Tubes may be reconditioned and retested provided reconditioning does not adversely effect the minimum wall thickness or other properties of the tube specification requirements. Upon agreement between purchaser and manufacturer, the referee method, employing ultrasonic testing, may be employed for retesting tubes rejected by the eddy-current test. The calibration standard for this test shall be identical to that required for the eddy-current test.

S2. Nondestructive Eddy-Current Testing (Select Commercial Grade)

S2.1 The manufacturer shall test the tubing using the procedure outlined in Supplementary Requirement S1, except for the notch standards, which shall be as indicated in Table 6.

S3. Report

S3.1 A report shall be furnished by the manufacturer to include a record of all tests performed to qualify material to this specification. This record shall include numbers of tests performed and qualitative or quantitative results as is applicable.

S4. Intergranular Corrosion Tests

S4.1 When specified, material shall pass intergranular corrosion test conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE 4 — Practice E requires testing on the sensitized condition for low carbon grades, and on the as-shipped condition for other grades.

SPECIFICATION FOR CARBON AND ALLOY STEEL PIPE, ELECTRIC-FUSION-WELDED FOR HIGH-PRESSURE SERVICE AT HIGH TEMPERATURES

SA-691

(Identical with ASTM Specification A 691-93 except that the following additional requirements apply.)

All products furnished under this SA specification are intended for application under the rules of Section III of the ASME Boiler and Pressure Vessel Code. Manufacture of such products is limited to manufacturers who hold the appropriate ASME Certificate of Authorization and Code Symbol Stamp. In addition to conforming to this specification, the manufacturer shall meet all applicable requirements of Section III of the Code. The plate used to fabricate the pipe shall conform to the applicable SA specification in the ASME Boiler and Pressure Vessel Code, Section II. The joints shall be full penetration butt welds as obtained by double welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside. Welds using metal backing strips which remain in place are excluded. The product is subject to all requirements of Section III of the Code including welding, heat treatment, nondestructive examination, authorized inspection at the point of manufacture, and application of the Code Symbol Stamp.

The applicable ASME Partial Data Report Form, signed by an Authorized Inspector, and a certified mill test report shall be furnished for each lot of pipe, as defined by requirement S12 of this specification. Each length of pipe shall be marked in such a manner as to identify each piece with the lot and the certified mill test report.

1. Scope

1.1 This specification covers carbon and alloy steel pipe, electric-fusion-welded with filler metal added, fabricated from pressure-vessel-quality plate of several analyses and strength levels and suitable for high-pressure service at high temperatures. Heat treatment may or may not be required to attain the desired mechanical properties or to comply with applicable code requirements. Supplementary requirements are provided for use when additional testing or examination is desired.

1.2 The specification nominally covers pipe 16 in. (405 mm) in outside diameter and larger with wall thicknesses up to 3 in. (75 mm) inclusive. Pipe having other dimensions may be furnished provided it complies with all other requirements of this specification.

1.3 Several grades and classes of pipe are provided.

1.3.1 *Grade* designates the type of plate used as listed in Table 1.

1.3.2 *Class* designates the type of heat treatment performed in the manufacture of the pipe, whether the weld is radiographically examined, and whether the pipe has been pressure tested as listed in 1.3.3.

1.3.3 Class designations are as follows (Note):

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see Section
10	none	none	none
11	none	9	none
12	none	9	8.3
13	none	none	8.3
20	stress relieved, see 5.3.1	none	none
21	stress relieved, see 5.3.1	9	none
22	stress relieved, see 5.3.1	9	8.3
23	stress relieved, see 5.3.1	none	8.3
30	normalized, see 5.3.2	none	none
31	normalized, see 5.3.2	9	none
32	normalized, see 5.3.2	9	8.3
33	normalized, see 5.3.2	none	8.3
40	normalized and tempered, see 5.3.3	none	none
41	normalized and tempered, see 5.3.3	9	none

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see Section
42	normalized and tempered, see 5.3.3	9	8.3
43	normalized and tempered, see 5.3.3	none	8.3
50	quenched and tempered, see 5.3.4	none	none
51	quenched and tempered, see 5.3.4	9	none
52	quenched and tempered, see 5.3.4	9	8.3
53	quenched and tempered, see 5.3.4	none	8.3

NOTE — Selection of materials should be made with attention to temperature of service. For such guidance, Specification A 20/A 20M may be consulted.

1.4 Optional requirements of a supplementary nature are provided, calling for additional tests and control of repair welding, when desired.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels
A 204/A 204M Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum
A 299/A 299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 387/A 387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates
A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
A 537/A 537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel
E 165 Practice for Liquid Penetrant Inspection Method
E 350 Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron
E 709 Practice for Magnetic Particle Examination

2.2 *ASME Boiler and Pressure Vessel Code:*

Section II, Material Specifications
Section III, Nuclear Power Plant Components
Section VIII, Unfired Pressure Vessels
Section IX, Welding Qualifications

3. Terminology

3.1 *Description of Term Specific to This Standard:*

3.1.1 A *lot* shall consist of 200 ft (61 m) or fraction thereof of pipe from the same heat of steel.

3.1.1.1 The description of a lot may be further restricted by use of Supplementary Requirement S12.

4. Ordering Information

4.1 The inquiry and order for material under this specification should include the following information:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of the material (steel pipe, electric-fusion-welded),

4.1.3 Specification number,

4.1.4 Grade and class designations (see 1.3),

4.1.5 Size (inside or outside diameter, nominal or minimum wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish,

4.1.8 Purchase options, if any (see 5.2.3, 11.3, 11.4, 13.1), and

4.1.9 Supplementary requirements, if any (refer to S1 through S12).

5. Materials and Manufacture

5.1 *Materials* — The steel plate material shall conform to the requirements of the applicable plate specification for the pipe grade ordered as listed in Table 1.

5.2 *Welding:*

5.2.1 The joints shall be double-welded full-penetration welds made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

5.2.2 The welds shall be made either manually or automatically by an electric process involving the deposition of filler metal.

5.2.3 The welded joints shall have positive reinforcement at the center of each side of the weld, but no more than $\frac{1}{8}$ in. (3.2 mm). This reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour

of the reinforcement shall be smooth, and the deposited metal shall be fused smoothly and uniformly into the plate surface.

5.2.4 When radiographic examination in accordance with 9.1 is to be used, the weld reinforcement shall be governed by the more restrictive provisions of UW-51 of Section VIII of the ASME Boiler and Pressure Vessel Code instead of 5.2.3 of this specification.

5.3 *Heat Treatment* — All classes other than 10, 11, 12, and 13 shall be heat treated in a furnace controlled to ±25°F (14°C) and equipped with a recording pyrometer so that heating records are available. Heat treating after forming and welding shall be to one of the following:

5.3.1 Classes 20, 21, 22, and 23 pipe shall be uniformly heated within the post-weld heat-treatment temperature range indicated in Table 2 for a minimum of 1 h/in. of thickness or for 1 h, whichever is greater.

5.3.2 Classes 30, 31, 32, and 33 pipe shall be uniformly heated to a temperature in the austenitizing range and not exceeding the maximum normalizing temperature indicated in Table 2 and subsequently cooled in air at room temperature.

5.3.3 Classes 40, 41, 42, and 43 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of ½ h/in. of thickness or for ½ h, whichever is greater, and air cooled.

5.3.4 Classes 50, 51, 52, and 53 pipe shall be uniformly heated to a temperature in the austenitizing range, and not exceeding the maximum quenching temperature indicated in Table 2 and subsequently quenched in water or oil. After quenching, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at that temperature for a minimum of ½ h/in. of thickness or for ½ h, whichever is greater, and air cooled.

6. General Requirements

6.1 Only the following sections of Specification A 530 shall apply: 1, 2, 7, 8, 14, 16, 17, 19, 20, 21, and 22 of the current edition of Specification A 530. Section 6 of Specification A 530 shall apply only for classes requiring hydrostatic testing.

7. Chemical Requirements

7.1 *Product Analysis of Plate* — The pipe manufacturer shall make an analysis of each mill heat of plate material. The product analysis so determined shall meet the requirements of the plate specification to which the material was ordered.

7.2 *Product Analysis of Weld* — The pipe manufacturer shall make an analysis of finished deposited weld metal from each 200 ft (61 m) or fraction thereof. Analysis shall conform to the welding procedure for deposited weld metal.

7.3 Analysis may be taken from the mechanical test specimens. The results of the analyses shall be reported to the purchaser.

7.4 If the analysis of one of these tests specified in 7.1 or 7.2 does not conform to the requirements specified, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified. Nonconforming pipe shall be rejected.

8. Mechanical Requirements

8.1 *Tension Test:*

8.1.1 *Requirements* — Transverse tensile properties of the welded joint shall meet the minimum requirements for ultimate tensile strength of the specified plate material.

8.1.2 *Number of Tests* — One test specimen shall be made to represent each lot of finished pipe.

8.1.3 *Test Specimen Location and Orientation* — The test specimen shall be made transverse to the weld at the end of the finished pipe and may be flattened cold before final machining to size.

8.1.4 *Test Method* — The test specimen shall be made in accordance with QW-150 in Section IX of the ASME Boiler and Pressure Vessel Code. The test specimen shall be tested at room temperature in accordance with Test Methods and Definitions A 370.

8.2 *Transverse-Guided-Weld-Bend Tests:*

8.2.1 *Requirements* — The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. (3.2 mm) in any direction be present in the weld metal or between the weld and the pipe metal after bending. Cracks that originate along the edges of the specimens during testing, and that are less than ¼ in. (6.3 mm) in any direction shall not be considered.

8.2.2 *Number of Tests* — One test (two specimens) shall be made to represent each lot of finished pipe.

8.2.3 *Test Specimen Location and Orientation* — Two bend test specimens shall be taken transverse to the weld at the end of the finished pipe. As an alternative, by agreement between the purchaser and the manufacturer, the test specimens may be taken from a test plate of the same material as the pipe, the test plate being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal weld seam.

8.2.4 *Test Method* — Bend tests shall be made in accordance with Test Methods and Definitions A 370, A2.5.1.7. For wall thicknesses over $^{3}/_{8}$ in. (9.5 mm) but less than $^{3}/_{4}$ in. (19.0 mm) side-bend tests may be made instead of the face and root-bend tests. For wall thicknesses $^{3}/_{4}$ in. and over both specimens shall be subjected to the side-bend test.

8.3 *Pressure Test* — Classes X2 and X3, pipe shall be tested in accordance with Section 20 of Specification A 530.

9. Radiographic Examination

9.1 The full length of each weld of classes X1 and X2 shall be radiographically examined in accordance with requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Paragraph UW-51.

9.2 Radiographic examination may be performed prior to heat treatment.

10. Rework

10.1 *Elimination of Surface Imperfections* — Unacceptable surface imperfections shall be removed by grinding or machining. The remaining thickness of the section shall be no less than the minimum specified in Section 11. The depression after grinding or machining shall be blended uniformly into the surrounding surface.

10.2 *Repair of Base Metal Defects by Welding:*

10.2.1 The manufacturer may repair, by welding, base metal where defects have been removed, provided the depth of the repair cavity as prepared for welding does not exceed $^{1}/_{3}$ of the nominal thickness, and the requirements of 10.2.2, 10.2.3, 10.2.4, 10.2.5, and 10.2.6 are met. Base metal defects in excess of these may be repaired with prior approval of the customer.

10.2.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair welding.

10.2.3 The welding procedure and welders or welding operators are to be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.2.4 The full length of the repaired pipe shall be heat treated after repair in accordance with the requirements of the pipe class specified.

10.2.5 Each repair weld of a defect where the cavity, prepared for welding, has a depth exceeding the lesser of $^{3}/_{8}$ in. (9.5 mm) or 10 % of the nominal thickness shall be examined by radiography in accordance with the methods and the acceptance standards of Section 9.

10.2.6 The repair surface shall be blended uniformly into the surrounding base metal surface and examined and accepted in accordance with Supplementary Requirements S6 or S8.

10.3 *Repair of Weld Metal Defects by Welding:*

10.3.1 The manufacturer may repair weld metal defects if he meets the requirements of 10.2.3, 10.2.4, 10.3.2, 10.3.3, and 10.4.

10.3.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the repair cavity examined and accepted in accordance with Supplementary Requirements S7 or S9.

10.3.3 The weld repair shall be blended uniformly into the surrounding metal surfaces and examined and accepted in accordance with 9.1 and with Supplementary Requirements S7 or S9.

10.4 *Retest* — Each length of repaired pipe of a class requiring a pressure test shall be hydrostatically tested following repair.

11. Dimensions, Mass, and Permissible Variations

11.1 The wall thickness and weight for welded pipe furnished to this specification shall be governed by the requirements of the specification to which the manufacturer ordered the plate.

11.2 Permissible variations in dimensions at any point in a length of pipe shall not exceed the following:

11.2.1 *Outside Diameter* — Based on circumferential measurement, ±0.5 % of the specified outside diameter.

11.2.2 *Out-of-Roundness* — The difference between major and minor outside diameters, 1%.

11.2.3 *Alignment* — Using a 10 ft (3 m) straightedge placed so that both ends are in contact with the pipe, $\frac{1}{8}$ in. (3.2 mm).

11.2.4 *Thickness* — The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. (0.3 mm) under the specified nominal thickness.

11.3 Circumferential welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

11.4 Lengths with unmachined ends shall be within −0, +$\frac{1}{2}$ in. (−0, +13 mm) of that specified. Lengths with machined ends shall be as agreed between the manufacturer and the purchaser.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall be free of injurious defects and shall have a workmanlike finish. This requirement is to mean the same as the identical requirement that appears in Specification A 20/A 20M with respect to steel plate surface finish.

13. Product Marking

13.1 The marking shall be stenciled using a suitable heat-resistant paint or metal stamped using low-stress stamps. Wall thicknesses under 0.500 in. (12.7 mm) shall not be metal stamped without prior approval. The purchaser may specify that material 0.500 in. (12.7 mm) and over shall not be metal stamped.

13.2 In addition to the marking provision of Specification A 530, the class marking in accordance with 1.3.3 shall follow the grade marking, for example, 3CR-33.

13.3 *Bar Coding* — In addition to the requirements in 13.1 and 13.2, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

TABLE 1
PLATE MATERIALS

Pipe Grade	Type of Steel	ASTM Specification		HB, max[A]
		Number	Grade	
CM-65	carbon-molybdenum steel	A 204/A 204M	A	201
CM-70	carbon-molybdenum steel	A 204/A 204M	B	201
CM-75	carbon-molybdenum steel	A 204/A 204M	C	201
CMSH-70	carbon-manganese-silicon steel, normalized	A 537/A 537M	1	
CMS-75	carbon-manganese-silicon steel	A 299/A 299M	. . .	. . .
CMSH-80	carbon-manganese-silicon steel, quenced and tempered	A 537/A 537M	2	
½CR	½% chromium, ½% molybdenum steel	A 387/A 387M	2	201
1CR	1% chromium, ½% molybdenum steel	A 387/A 387M	12	201
1¼CR	1¼% chromium, ½% molybdenum steel	A 387/A 387M	11	201
2¼CR	2¼% chromium, 1% molybdenum steel	A 387/A 387M	22	201
3CR	3% chromium, 1% molybdenum steel	A 387/A 387M	21	201
5CR	5% chromium, ½% molybdenum steel	A 387/A 387M	5	225
9CR	9% chromium, 1% molybdenum steel	A 387/A 387M	9	241

[A] Hardness values listed are applicable to S3.

TABLE 2
HEAT TREATMENT PARAMETERS

Pipe Grade	ASTM Specification	Post-Weld Heat-Treat Temperature Range (Stress Relieving), °F (°C)	Normalizing Temperature, max, °F (°C)	Quenching Temperature, max, °F (°C)	Tempering Temperature, min, °F (°C)
CM-65	A 204/A 204M	1100 to 1200 (590 to 650)	1700 (925)	. . .	. . .
CM-70	A 204/A 204M	1100 to 1200 (590 to 650)	1700 (925)	. . .	. . .
CM-75	A 204/A 204M	1100 to 1200 (590 to 650)	1700 (925)	. . .	. . .
CMSH-70	A 537/A 537M	1100 to 1200 (590 to 650)	1700 (925)	. . .	. . .
CMS-75	A 299/A 299M	1100 to 1200 (590 to 650)	1700 (925)	. . .	. . .
CMSH-80	A 537/A 537M	1100 to 1200 (590 to 650)	[A]	1700 (925)	1100 to 1250 (590 to 675)
½CR	A 387/A 387M	1100 to 1300 (590 to 705)	1850 (1010)	1700 (925)	1150 to 1375 (620 to 745)
1CR	A 387/A 387M	1100 to 1350 (590 to 730)	1850 (1010)	1700 (925)	1150 to 1375 (620 to 745)
1¼CR	A 387/A 387M	1100 to 1375 (590 to 745)	1850 (1010)	1700 (925)	1150 to 1375 (620 to 745)
2¼CR	A 387/A 387M	1200 to 1400 (650 to 760)	1850 (1010)	1700 (925)	1250 to 1400 (675 to 760)
3CR	A 387/A 387M	1200 to 1400 (650 to 760)	1850 (1010)	1700 (925)	1250 to 1400 (675 to 760)
5CR	A 387/A 387M	1200 to 1400 (650 to 760)	1850 (1010)	1650 (900)	1300 to 1400 (705 to 760)
9CR	A 387/A 387M	1325 to 1375 (715 to 745)	[B]	. . .	1325 to 1375 (715 to 745)

[A] Requires quencing and tempering.
[B] 9 CR steel is an air-hardenable steel, at times retaining austenite down to near atmospheric temperature. Good practice is to allow the steel to cool to 150°F or lower before subjecting the steel to a tempering treatment or post-weld heat treatment.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Tension and Bend Tests

S1.1 Tension tests in accordance with 8.1 and bend tests in accordance with 8.2 shall be made on specimens representing each length of pipe.

S2. Charpy V-Notch Test (for pipe with nominal wall thickness of ½ in. (12.7 mm) and greater)

S2.1 *Requirements* — The acceptable test energies shall be as shown in Table A1.15 of Specification A 20/A 20M for the applicable plate specification unless otherwise stated in the order. As an alternative, the test temperature may be 10°F (−12°C).

S2.2 *Number of Specimens* — Each test shall consist of at least three specimens.

S2.2.1 One base-metal test shall be made from one pipe length per heat, per heat-treat charge, and per nominal wall thickness.

S2.2.2 One weld-metal and one heat-affected zone (HAZ) metal test shall be made in accordance with NB-4335 of Section III of the ASME Boiler and Pressure Vessel Code.

S2.3 *Test Specimen Location and Orientation:*

S2.3.1 Base-metal specimens of stress-relieved, normalized, and normalized and tempered pipe shall be taken in accordance with the provisions for tension specimens in the body of this specification.

S2.3.2 Base-metal specimens of quenched and tempered pipe shall be taken in accordance with the provisions of NB-2225 of Section III of the ASME Boiler and Pressure Vessel Code.

S3. Hardness Test

S3.1 Hardness determination shall be made on both ends of each length of pipe to the parent metal, weld, and the heat-affected zone and must meet the hardness requirements in Table 1.

S4. Product Analysis

S4.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical requirements prescribed in the applicable specification listed in Table 1 shall be rejected.

S5. Metallography

S5.1 The manufacturer shall furnish one photomicrograph to show the microstructure at 100× magnification of the weld metal or base metal of the pipe in the as-finished condition. The purchaser shall state in the order: the material, base metal or weld, and the number and locations of tests to be made. This test is for information only.

S6. Magnetic Particle Examination of Base Metal

S6.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E 709. Accessible is defined as: All outside surfaces, all inside surfaces pipe 24 in. (610 mm) in diameter and greater, and inside surfaces of pipe less than 24 in. in diameter for a distance of one pipe diameter from the ends.

S6.2 Butt-weld end preparations are to be completely magnetic-particle examined in accordance with Practice E 709.

S6.3 *Acceptance Standards,* shall be by agreement between the manufacturer and the purchaser.

S7. Magnetic Particle Examinations of Weld Metal

S7.1 All accessible welds shall be examined in accordance with Practice E 709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. (610 mm) in diameter and greater, and inside surfaces of pipe less than 24 in. in diameter for a distance of one pipe diameter from the ends.

S7.2 Butt-weld end preparations are to be completely magnetic-particle examined in accordance with Practice E 709.

S7.3 *Acceptance Standards,* shall be by agreement between the manufacturer and the purchaser.

S8. Liquid Penetrant Examination of Base Metal

S8.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E 165. Accessible is as defined in S7.1.

S8.2 Butt-weld end preparations are to be completely liquid penetrant examined in accordance with Practice E 165.

S8.3 *Acceptance Standards,* shall be by agreement between the manufacturer and the purchaser.

S9. Liquid Penetrant Examination of Weld Metal

S9.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E 165. Accessible is as defined in S6.1.

S9.2 *Acceptance Standards,* shall be by agreement between the manufacturer and the purchaser.

S10. Ultrasonic Test

S10.1 *Plate in Flat:*

S10.1.1 One hundred percent on one surface shall be scanned.

S10.1.2 Straight search shall be used in accordance with Specification A 435/A 435M.

S10.1.3 Acceptance standards shall be in accordance with Specification A 435/A 435M or as by agreement between the manufacturer and the purchaser.

S11. Repair Welding

S11.1 Repair of base metal defects by welding shall be done only with customer approval.

S12. Description of Term

S12.1 *lot* — all pipe of the same mill heat of plate material and wall thickness (within $\pm 1/4$ in. (6.4 mm)) heat treated in one furnace charge. For pipe that is not heat treated or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft (61 m) or fraction thereof of all pipe of the same mill heat of plate material and wall thickness (within $\pm 1/4$ in. (6.4 mm)), subjected to the same heat treatment. For pipe heat treated in batch-type furnace that is automatically controlled within a 50°F (28°C) range and is equipped with recording pyrometers so that heating records are available, a lot shall be defined the same as for continuous furnaces.

SPECIFICATION FOR PRECIPITATION-HARDENING STAINLESS AND HEAT-RESISTING STEEL PLATE, SHEET, AND STRIP

SA-693

(Identical with ASTM Specification A 693-93.)

1. Scope

1.1 This specification covers precipitation-hardening stainless steel plate, sheet, and strip. The mechanical properties of these steels are developed by suitable low-temperature heat treatments generally referred to as precipitation hardening.

1.2 These steels are used for parts requiring corrosion resistance and high-strength at room temperature or at temperatures up to 600°F [315°C]. Some of these steels are particularly suitable for moderate to severe drawing and forming in the solution-treated condition. Others are capable of mild forming only. They are suitable for machining in the solution-annealed condition, after which they may be hardened to the mechanical properties specified in this standard without danger of cracking or distortion.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Reference Documents

2.1 *ASTM Standards:*

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *SAE Standard:*

SAE J1086 Recommended Practice for Numbering Metals and Alloys (UNS)

3. General Requirements

3.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 480/A 480M or as specified in the following:

3.1.1 Definitions,

3.1.2 General requirements for delivery.

3.1.3 *Ordering Information:*

3.1.3.1 In addition to the requirements of A 480/A 480M, the heat treatment (see Section 6) must be specified on the purchase order.

4. Materials and Manufacture

4.1 The steel shall be melted by one of the following processes:

4.1.1 Electric furnace (with separate degassing and refining optional),

4.1.2 Vacuum furnace, and

4.1.3 One of the former followed by:

4.1.3.1 Consumable remelting in vacuum, inert gas, or electroslag, or

4.1.3.2 Electron beam refining.

4.1.4 Other commercial melting methods as agreed upon between purchaser and seller are acceptable.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition specified in Table 1, and shall conform to applicable requirements specified in the current edition of Specification A 480/A 480M.

6. Heat Treatment of Product

6.1 Material shall be furnished in the solution-annealed condition as noted in Tables 2 and 2A unless otherwise specified by the purchaser on the purchase order.

7. Mechanical Properties

7.1 The material, as represented by mechanical test specimens, shall conform to the mechanical property requirements specified in Table 3 and shall be capable of developing the properties in Table 4 when heat treated as specified in 9.1.

8. Bending Requirements

8.1 Samples cut from the solution-annealed plate, sheet, or strip shall withstand cold bending as specified in Table 5 without cracking on the outside of the bent portion.

9. Heat Treatment of Test Specimens

9.1 Samples cut from the plate, sheet, or strip shall conform to the mechanical properties of Table 4 when precipitation hardened as specified in Tables 2 and 2A.

TABLE 1
CHEMICAL REQUIREMENTS[A]

		Composition, %											
UNS Designation[B]	Type	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Aluminum	Molybdenum	Titanium	Copper	Other Elements[C]
S 17400	630	0.07	1.00	0.040	0.030	1.00	15.00–17.50	3.00–5.00	. . .	. . .	. . .	3.00–5.00	[D]
S 17700	631	0.09	1.00	0.040	0.030	1.00	16.00–18.00	6.50–7.75	0.75–1.50	. . .	. . .	. . .	. . .
S 15700	632	0.09	1.00	0.040	0.030	1.00	14.00–16.00	6.50–7.75	0.75–1.50	2.00–3.00	. . .	. . .	. . .
S 35000	633	0.07–0.11	0.50–1.25	0.040	0.030	0.50	16.00–17.00	4.00–5.00	. . .	2.50–3.25	. . .	. . .	[E]
S 35500	634	0.10–0.15	0.50–1.25	0.040	0.030	0.50	15.00–16.00	4.00–5.00	. . .	2.50–3.25	. . .	. . .	[F]
S 17600	635	0.08	1.00	0.040	0.030	1.00	16.00–17.50	6.00–7.50	0.40	. . .	0.40–1.20	. . .	. . .
S 36200	XM-9	0.05	0.50	0.030	0.030	0.30	14.00–14.50	6.25–7.00	0.10	0.30	0.60–0.90	. . .	. . .
S 15500	XM-12	0.07	1.00	0.040	0.030	1.00	14.00–15.50	3.50–5.50	. . .	. . .	. . .	2.50–4.50	[D]
S 13800	XM-13	0.05	0.20	0.010	0.008	0.10	12.25–13.25	7.50–8.50	0.90–1.35	2.00–2.50	. . .	. . .	[G]
S 45500	XM-16	0.05	0.50	0.040	0.030	0.50	11.00–12.50	7.50–9.50	. . .	0.50	0.80–1.40	1.50–2.50	[F]
S 45000	XM-25	0.05	1.00	0.030	0.030	1.00	14.00–16.00	5.00–7.00	. . .	0.50–1.00	. . .	1.25–1.75	[H]

[A] Limits are in percent maximum unless shown as a range or stated otherwise.
[B] New designation established in accordance with Practice E 527 and SAE J1086.
[C] The terms Columbium (Cb) and Niobium (Nb) both relate to the same element.
[D] Columbium plus tantalum 0.15–0.45.
[E] Nitrogen 0.07–0.13.
[F] Columbium plus tantalum 0.10–0.50.
[G] Nitrogen 0.01.
[H] Columbium 8 times carbon minimum.

TABLE 2
HEAT TREATMENT, °F

UNS Designation	Type	Solution Treatment	Precipitation Hardening Treatment[A]
S17400	630	1925 ± 50°F (cool as required)	900 ± 15°F, 1 h, air cool. 925 ± 15°F, 4 h, air cool. 1025 ± 15°F, 4 h, air cool. 1075 ± 15°F, 4 h, air cool. 1100 ± 15°F, 4 h, air cool. 1150 ± 15°F, 4 h, air cool. (1400 ± 15°F, 2 h, air cool + 1150 ± 15°F, 4 h, air cool).
S17700	631	1950 ± 25°F (cool as required)	1750 ± 15°F, hold 10 min, cool rapidly to room temperature. Cool within 24 h, to −100 ± 10°F, hold not less than 8 h. Warm in air to room temperature. Heat to 950 ± 10°F, hold 1 h, air cool.
		Alternative Treatment: 1400 ± 25°F, hold 90 min, cool to 55 ± 5°F within 1 h. Hold not less than 30 min, heat to 1050 ± 10°F, hold for 90 min, air cool.	
S15700	632	1950 ± 25°F (cool as required)	Same as Type 631
S35000	632	1710 ± 25°F (water quench), hold not less than 3 h at −100°F or lower.	850 ± 15°F, 3 h, air cool. 1000 ± 15°F, 3 h, air cool.
S35500	634[B]	1900 ± 25°F (quench), hold not less than 3 h at −100°F or lower.	1750 −10°F for not less than 10 min, but not more than 1 h, water quench. Cool to not higher than −100°F, hold for not less than 3 h. Temper at 1000 ± 25°F, holding for not less than 3 h.
S17600	635	1900 ± 25°F (air cool)	950 ± 15°F, 30 min, air cool. 1000 ± 15°F, 30 min, air cool. 1050 ± 15°F, 30 min, air cool.
S36200	XM-9	1550 ± 25°F (air cool)	900 ± 10°F, 8 h, air cool.
S15500	XM-12	1900 ± 25°F (cool as required)	Same as Type 630
S13800	XM-13	1700 ± 25°F (cool as required to below 60°F)	950 ± 10°F, 4 h, air cool. 1000 ± 10°F, 4 h, air cool.
S45500	XM-16	1525 ± 25°F (water quench)	900 ± 10°F, 4 h, air cool, or 950 ± 10°F, 4 h, air cool.
S45000	XM-25	1900 ± 25°F (cool rapidly)	900 ± 15°F, 4 h, air cool. 1000 ± 15°F, 4 h, air cool. 1150 ± 15°F, 4 h, air cool.

[A] Times refer to time material is at temperature.
[B] Equalization and over-tempering treatment: 1425 ± 50°F for not less than 3 h, cool to room temperature, heat to 1075 ± 25°F for not less than 3 h.

TABLE 2A
HEAT TREATMENT, °C

UNS Designation	Type	Solution Treatment	Precipitation Hardening Treatment[A]
S17400	630	1050 ± 25°C (cool as required)	482 ± 8°C, 1 h, air cool. 496 ± 8°C, 4 h, air cool. 552 ± 8°C, 4 h, air cool. 579 ± 8°C, 4 h, air cool. 593 ± 8°C, 4 h, air cool. 621 ± 8°C, 4 h, air cool. (760 ± 8°C, 2 h, air cool + 621 ± 8°C, 4 h, air cool).
S17700	631	1065 ± 15°C (water quench)	954 ± 8°C, hold 10 min, cool rapidly to room temperature. Cool within 24 h to −73°C ± 6°C, hold not less than 8 h. Warm in air to room temperature. Heat to 510 ± 6°C, hold 1 h, air cool.
		Alternative Treatment	
		760 ± 15°C, hold 90 min, cool to 15 ± 3°C within 1 h. Hold not less than 30 min, heat to 566 ± 6°C, hold for 90 min, air cool.	
S15700	632	1038 ± 15°C (water quench)	Same as Type 631
S35000	633	930 ± 15°C (water quench), hold not less than 3 h at −75°C or lower.	455 ± 8°C, 3 h, air cool. 540 ± 8°C, 3 h, air cool.
S35500	634[B]	1038 ± 15°C (quench), hold not less than 3 h at −73°C or lower.	954 ± 6°C for not less than 10 min, but not more than 1 h, water quench. Cool to not higher than −73°C, hold for not less than 3 h. Temper at 538 ± 15°C, holding for not less than 3 h.
S17600	635	1038 ± 15°C (air cool)	510 ± 8°C, 30 min, air cool. 538 ± 8°C, 30 min, air cool. 566 ± 8°C, 30 min, air cool.
S36200	XM-9	843 ± 15°C (air cool)	482 ± 8°C, 8 h, air cool.
S15500	XM-12	1038 ± 15°C (cool as required)	Same as Type 630
S13800	XM-13	927 ± 15°C (cool as required to below 60°C)	510 ± 6°C, 4 h, air cool. 538 ± 6°C, 4 h, air cool.
S45500	XM-16	829 ± 15°C (water quench)	482 ± 6°C, 4 h, air cool, or 510 ± 6°C, 4 h, air cool.
S45000	XM-25	1038 ± 15°C (cool rapidly)	482 ± 8°C, 4 h, air cool. 538 ± 8°C, 4 h, air cool. 621 ± 8°C, 4 h, air cool.

[A] Times refer to time material is at temperature.
[B] Equalization and over-tempering treatment: 774 ± 25°C for not less than 3 h, cool to room temperature, heat to 579 ± 15°C for not less than 3 h.

TABLE 3
MECHANICAL TEST REQUIREMENTS IN SOLUTION-TREATED CONDITION

Type		Tensile Strength, max		Yield Strength, max		Elongation in 2 in. or 50 mm, min, %	Hardness, max	
		ksi	MPa	ksi	MPa		Rockwell	Brinell
630	0.015 to 4.0 in. (0.38 to 102 mm)	185	1255	160	1105	3	C38	363
631	0.010 in. (0.25 mm) and under	150	1035	65	450	. . .	. . .	. . .
	Over 0.010 to 4.0 in. (0.25 to 102 mm)	150	1035	55	380	20	B92	. . .
632	0.0015 to 4.0 in. (0.038 to 102 mm)	150	1035	65	450	25	B100	. . .
633	0.001 to 0.0015 in. (0.03 to 0.038 mm), excl	200	1380	90	620	8	C30	. . .
	0.0015 to 0.002 in. (0.03 to 0.05 mm), excl	200	1380	88	605	8	C30	. . .
	0.002 to 0.005 in. (0.05 to 0.13 mm), excl	200	1380	86	595	8	C30	. . .
	0.005 to 0.010 in. (0.13 to 0.25 mm), excl	200	1380	85	585	8	C30	. . .
	Over 0.010 in. (0.254 mm)	200	1380	85	585	12	C30	. . .
634[A]	Plate	. . .	. . .	. . .	. . .	. . .	C40	. . .
635	0.030 in. (0.76 mm) and under	120	825	75	515	3	C32	. . .
	Over 0.030 to 0.060 in. (0.76 to 1.52 mm)	120	825	75	515	4	C32	. . .
	Over 0.060 in. (1.52 mm)	120	825	75	515	5	C32	. . .
XM-9	Over 0.010 in. (0.25 mm)	150	1035	125	860	4	C28	. . .
XM-12	0.0015 to 4.00 in. (0.038 to 101.6 mm)	. . .	. . .	. . .	. . .	. . .	C38	363
XM-13	0.0015 to 4.00 in. (0.038 to 101.6 mm)	. . .	. . .	. . .	. . .	. . .	C38	363
XM-16	0.010 in. (0.25 mm) and greater	175	1205	160	1105	3	C36	331
XM-25[B]	0.010 in. (0.25 mm) and greater	165	1205	150	1035	4	C33	311
[B] XM-25 also furnished to the following minimum properties:		130	895	90	620	4	C25	255

[A] Solution-treated, equalized, and over-tempered plate only.

TABLE 4
MECHANICAL TEST REQUIREMENTS AFTER PRECIPITATION HARDENING TREATMENT

Grade	Hardening or Precipitation Treatment or both, °F (°C)	Thickness, in. (mm)	Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %[A]	Reduction of Area, min, %[A]	Hardness, min		Impact Charpy V, min[B]	
			ksi	MPa	ksi	MPa			Rockwell, min/max	Brinell, min/max	ft·lbf	J
630 and XM-12	900 (482)	Under 0.1875 (4.762)	190	1310	170	1170	5	...	C40/C48	...	...	...
		0.1875 to 0.625 (4.762 to 15.88)	190	1310	170	1170	8	25	C40/C48	388/477	...	...
		0.626 to 4.0 (15.90 to 102)	190	1310	170	1170	10	30	C40/C48	388/477	...	...
	925 (496)	Under 0.1875 (4.762)	170	1170	155	1070	5	...	C38/C48	...	...	...
		0.1875 to 0.625 (4.762 to 15.88)	170	1170	155	1070	8	25	C38/C47	375/477	...	...
		0.626 to 4.0 (15.90 to 102)	170	1170	155	1070	10	30	C38/C47	375/477	...	...
	1025 (552)	Under 0.1875 (4.762)	155	1070	145	1000	5	...	C35/C43	...	...	...
		0.1875 to 0.625 (4.762 to 15.88)	155	1070	145	1000	8	30	C33/C42	321/415	10	14
		0.626 to 4.0 (15.90 to 102)	155	1070	145	1000	12	35	C33/C42	321/415	15	20
	1075 (579)	Under 0.1875 (4.762)	145	1000	125	860	5	...	C31/C40	...	...	...
		0.1875 to 0.625 (4.762 to 15.88)	145	1000	125	860	9	30	C29/C38	293/375	15	20
		0.626 to 4.0 (15.88 to 102)	145	1000	125	860	13	35	C29/C38	293/375	20	27
	1100 (593)	Under 0.1875 (4.762)	140	965	115	790	5	...	C31/C40	...	...	...
		0.1875 to 0.625 (4.762 to 15.88)	140	965	115	790	10	30	C29/C38	293/375	15	20
		0.626 to 4.0 (15.88 to 102)	140	965	115	790	14	35	C29/C38	293/375	20	27
	1150 (621)	Under 0.1875 (4.762)	135	930	105	725	8	...	C28/C38	...	...	...
		0.1875 to 0.625 (4.762 to 15.88)	135	930	105	725	10	35	C26/C36	269/352	25	34
		0.626 to 4.0 (15.88 to 102)	135	930	105	725	16	40	C26/C36	269/352	30	41
	1400 + 1150 (760 + 621)	Under 0.1875 (4.762)	115	790	75	515	9	...	C26/C36	255/331	...	...
		0.1875 to 0.625 (4.762 to 15.88)	115	790	75	515	11	40	C24/C34	248/321	55	75
		0.626 to 4.0 (15.88 to 102)	115	790	75	515	18	45	C24/C34	248/321	55	75
631	1400 (760) + plus 55 (15) + 1050 (566)	0.0015 to 0.0049 (0.038 to 0.124)	180	1240	150	1035	3	...	C38	...	...	...
		0.0050 to 0.0099 (0.127 to 0.251)	180	1240	150	1035	4	...	C38	...	...	...
		0.010 to 0.0199 (0.25 to 0.505)	180	1240	150	1035	5	...	C38	...	...	...
		0.020 to 0.1874 (0.51 to 4.760)	180	1240	150	1035	6	...	C38	...	...	...
		0.1875 to 0.625 (4.762 to 15.88)	170	1170	140	965	7	20	C38	352	...	...
	1750 (954) + minus 100 (73) + 950 (510)	0.0015 to 0.0049 (0.038 to 0.124)	210	1450	190	1310	1	...	C44	...	...	...
		0.0050 to 0.0099 (0.127 to 0.251)	210	1450	190	1310	2	...	C44	...	...	...
		0.010 to 0.0199 (0.25 to 0.505)	210	1450	190	1310	3	...	C44	...	...	...
		0.020 to 0.1874 (0.51 to 4.760)	210	1450	190	1310	4	...	C44	...	...	...
		0.1875 to 0.625 (4.762 to 15.88)	200	1380	180	1240	6	20	C43	401	...	...
	Cold rolled at mill	0.0015 to 0.050 (0.038 to 1.27)	200	1380	175	1205	1	...	C41	...	...	...
	Cold rolled at mill + 900 (492)	0.0015 to 0.050 (0.038 to 1.27)	240	1655	230	1580	1	...	C46	...	...	...
632	1400 (760) + plus 55 (15) + 1050 (566)	0.0015 to 0.0049 (0.038 to 0.124)	190	1310	170	1170	2	...	C40	...	...	...
		0.0050 to 0.0099 (0.127 to 0.251)	190	1310	170	1170	3	...	C40	...	...	...
		0.010 to 0.0199 (0.25 to 0.505)	190	1310	170	1170	4	...	C40	...	...	...
		0.020 to 0.1874 (0.51 to 4.760)	190	1310	170	1170	5	...	C40	...	...	...
		0.1875 to 0.625 (4.762 to 15.88)	190	1310	170	1170	4	20	C40	375	...	...
	1750 (954) + minus 100 (73) + 950 (510)	0.0015 to 0.0049 (0.038 to 0.124)	225	1550	200	1380	1	...	C46	...	...	...
		0.0050 to 0.0099 (0.127 to 0.251)	225	1550	200	1380	2	...	C46	...	...	...
		0.010 to 0.0199 (0.25 to 0.505)	225	1550	200	1380	3	...	C46	...	...	...
		0.020 to 0.1874 (0.51 to 4.760)	225	1550	200	1380	4	...	C46	...	...	...
		0.1875 to 06.25 (4.762 to 15.88)	225	1550	200	1380	4	20	C45	429	...	...
	Cold rolled at mill	0.0015 to 0.050 (0.038 to 0.13)	200	1380	175	1205	1	...	C41	...	...	...
	Cold rolled at mill + 900 (482)	0.0015 to 0.050 (0.038 to 0.13)	240	1655	230	1585	1	...	C46	...	...	...

TABLE 4 (CONT'D)
MECHANICAL TEST REQUIREMENTS AFTER PRECIPITATION HARDENING TREATMENT

Grade	Hardening or Precipitation Treatment or both, °F (°C)	Thickness, in. (mm)	Tensile Strength, min		Yield Strength, min		Elongation in 2 in. or 50 mm, min, %[A]	Reduction of Area, min, %[A]	Hardness, min		Impact Charpy V, min[B]	
			ksi	MPa	ksi	MPa			Rockwell, min/max	Brinell, min/max	ft·lbf	J
633	850 (455)	0.0005 to 0.0015 (0.022 to 0.038)	185	1275	150	1035	2	...	C42	...	...	...
		0.0015 to 0.0020 (0.038 to 0.041)	185	1275	150	1035	4	...	C42	...	...	...
		0.0020 to 0.0100 (0.041 to 0.254)	185	1275	150	1035	6	...	C42	...	...	...
		0.0100 to 0.1875 (0.254 to 4.762)	185	1275	150	1035	8	...	C42	...	...	...
	1000 (540)	0.0005 to 0.0015 (0.022 to 0.038)	165	1140	145	1000	2	...	C36	...	...	...
		0.0015 to 0.0020 (0.038 to 0.041)	165	1140	145	1000	4	...	C36	...	...	...
		0.0020 to 0.0100 (0.0.41 to 0.254)	165	1140	145	1000	6	...	C36	...	...	...
		0.0100 to 0.1875 (0.254 to 4.762)	165	1140	145	1000	8	...	C36	...	...	...
634	850 (455)		190	1310	165	1140	10	...	...	...	...	...
	1000 (540)		170	1170	150	1035	12	...	C37	...	...	...
635	950 (510)	0.030 (0.76) and under	190	1310	170	1170	3	...	C39	...	...	...
		0.030 to 0.060 (0.76 to 1.52)	190	1310	170	1170	4	...	C39	...	...	...
		Over 0.060 (1.52)	190	1310	170	1170	5	...	C39	...	...	...
		Plate	190	1310	170	1170	8	25	C39	363	...	...
	1000 (540)	0.030 (0.76) and under	180	1240	160	1105	3	...	C37	...	...	...
		0.030 to 0.060 (0.76 to 1.52)	180	1240	160	1105	4	...	C37	...	...	...
		Over 0.060 (1.52)	180	1240	160	1105	5	...	C37	...	...	...
		Plate	180	1240	160	1105	8	30	C38	352	...	...
	1050 (565)	0.030 (0.76) and under	170	1170	150	1035	3	...	C35	...	...	...
		0.030 to 0.060 (0.76 to 1.52)	170	1170	150	1035	4	...	C35	...	...	...
		Over 0.060 (1.52)	170	1170	150	1035	5	...	C35	...	...	...
		Plate	170	1170	150	1035	8	30	C36	331	...	...
XM-13	950 (510)	Under 0.020 (0.51)	220	1515	205	1410	6	...	C45	...	...	...
		0.020 to 0.1874 (0.51 to 4.760)	220	1515	205	1410	8	...	C45	...	...	...
		0.1875 to 0.625 (4.760 to 15.88)	220	1515	205	1410	10	...	C45	...	...	...
		0.626 to 4.0 (15.90 to 102)	220	1515	205	1410	10	...	C45	429	...	...
	1000 (538)	Under 0.020 (0.51)	200	1380	190	1310	6	...	C43	...	...	...
		0.020 to 0.1874 (0.51 to 4.760)	200	1380	190	1310	8	...	C43	...	...	...
		0.1875 to 0.625 (4.760 to 15.88)	200	1380	190	1310	10	...	C43	...	...	...
		0.626 to 4.0 (15.90 to 102)	200	1380	190	1310	10	...	C43	401	...	...
XM-16	950 (510)	Up to 0.020 (0.51)	222	1525	205	1410	...	...	C44	...	...	...
		Over 0.020 to 0.062 (0.51 to 1.57)	222	1525	205	1410	3	...	C44	...	...	...
		Over 0.062 (1.57)	222	1525	205	1410	4	...	C44	...	...	...
XM-25	900 (482)	Up to 0.020 (0.51)	180	1240	170	1170	3	...	C40	...	...	...
		Over 0.020 to 0.062 (0.51 to 1.57)	180	1240	170	1170	4	...	C40	...	...	...
		Over 0.062 (1.57)	180	1240	170	1170	5	...	C40	...	...	...
	1000 (538)	Up to 0.020 (0.51)	160	1105	150	1035	5	...	C36	...	...	...
		Over 0.020 to 0.062 (0.51 to 1.57)	160	1105	150	1035	6	...	C36	...	...	...
		Over 0.062 (1.57)	160	1105	150	1035	7	...	C36	...	...	...
	1150 (621)	Up to 0.020 (0.51)	125	860	75	515	8	...	C26	...	...	...
		Over 0.020 to 0.062 (0.51 to 1.57)	125	860	75	515	9	...	C26	...	...	...
		Over 0.062 (1.57)	125	860	75	515	10	...	C26	...	...	...
XM-9	900 (482)	Over 0.010 (0.25)	180	1240	160	1105	3	...	C38	...	...	...

[A] Applicable to tests in the long transverse direction. Transverse to the direction of rolling and parallel to the product surface.
[B] Impact test is not required unless specified on the purchase order.

TABLE 5
BEND TEST REQUIREMENTS IN SOLUTION-TREATED CONDITION

Type	Size, in. (mm)	Cold Bend Degrees	Bend Test Mandrel
630		none required	
631	0.187 (4.76) and under	180	1 T[A]
	Over 0.187 to 0.275 (4.76 to 6.98)	180	3 T
632	0.187 (4.76) and under	180	1 T
	Over 0.187 to 0.275 (4.76 to 6.98)	180	3 T
633	Under 0.1875 (4.762)	180	2 T
634	0.187 to 0.249 (4.76 to 6.32)	130	3 T
	Over 0.249 to 0.750 (6.32 to 19.08)	90	3 T
635		none required	
XM-9	0.109 (2.77) and under	180	9 T
XM-12		none required	
XM-13		none required	
XM-16	Under 0.1875 (4.762)	180	6 T
XM-25	Under 0.1875 (4.762)	180	6 T

[A] T = thickness of sheet being tested.

SPECIFICATION FOR STEEL BARS, CARBON, HOT-WROUGHT, SPECIAL QUALITY, FOR FLUID POWER APPLICATIONS

SA-695

(Identical with ASTM Specification A 695-90b for Type B only.)

1. Scope

1.1 This specification covers hot-wrought, special quality, round carbon steel bars subject to mechanical property requirements and intended for fluid power applications.

98 **1.2** The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards*:

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

3. Classification

3.1 The bars are available only as hot-wrought rounds 3.0 in. [76 mm] in diameter and larger. Smaller sizes are specified and procured to a cold-finished specification.

3.2 The bars are furnished in the following types and grades:

Type	Composition, %
B	C 0.35 max., Mn 1.10 max., Si 0.15–0.35
Grade	Yield Strength, psi (MPa)
35	35,000 (240)
40	40,000 (275)

3.3 All grades are not available in all types and sizes. See Section 8.

4. Ordering Information

4.1 Orders for material under this specification should include the following information:

4.1.1 Quantity (weight or number of bars),

4.1.2 Name of material (carbon steel bars),

4.1.3 Condition (hot wrought),

4.1.4 Finish (if descaled required, so state) (Section 9 and S3),

4.1.5 Dimensions (diameter and length),

4.1.6 ASTM designation and date of issue,

4.1.7 Type and grade (Tables 1 and 2),

4.1.8 End use, and

4.1.9 Additions to the specification and supplementary requirements if required.

NOTE—A typical ordering description is as follows: 10,000 lb, Carbon Steel Bars, Hot Wrought, 4.5-in. diameter by 10 ft, ASTM

A 695 dated_____, Type A, Grade 40, End Use Accumulator Heads; Supplementary Requirement S1 Straightness 0.125 in. in any 5 ft.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 29/A 29M unless otherwise provided herein.

6. Materials and Manufacture

6.1 *Melting Practice* — The steel shall be made by one or more of the following primary processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting using electroslag remelting or vacuum arc remelting. Where secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

6.2 *Deoxidation* — Type B steels shall be silicon killed.

6.3 *Quality* — The bars shall be special quality.

6.4 *Hot Working* — The bars shall be hot wrought, as wrought.

7. Chemical Composition

7.1 The heat analysis shall conform to the requirements for chemical composition specified in Table 1.

8. Mechanical Properties

8.1 *Tensile Requirements*:

8.1.1 The material, as represented by the test specimens, shall conform to the tensile requirements specified in Table 2.

8.1.2 A deduction from the percentage of elongation specified in Table 2 of 1.0% shall be made for each 1.0 in. (25.4 mm) of specified diameter over 3.0 in. (76 mm) or fraction thereof to a maximum of 3%.

8.2 *Specimens* — Tension test specimens shall be taken longitudinally in accordance with Test Methods and Definitions A 370.

8.3 *Number of Tests* — One tension test shall be made from each lot. A lot shall consist of all bars of one size from one heat processed at one time.

8.4 *Test Methods* — Tension tests shall be made in accordance with Test Methods and Definitions A 370. The yield strength shall be determined by an extension under load of 0.5% of the gage length.

9. Workmanship, Finish, and Appearance

9.1 *Descaling*—When descaled bars are required, Supplementary Requirement S3 must be specified.

9.2 The bars shall be free of visible pipe and conditioned as necessary to remove injurious surface imperfections.

10. Certification and Test Reports

10.1 A manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the heat analysis and tension test results shall be furnished at the time of shipment. The report shall include the name of the manufacturer, ASTM designation number and year date and revision letter, if any, type and grade, heat number, and size.

11. Product Marking

11.1 The heat number shall be steel stamped on one end of each bar.

12. Keywords

98

12.1 carbon steel bars; hot-wrought steel bars; pressure-containing parts; steel bars

TABLE 1
CHEMICAL REQUIREMENTS (HEAT ANALYSIS), %

	Type B
Carbon, max	0.35
Manganese, max	1.10
Phosphorus, max	0.040
Sulfur	0.050
Silicon	0.15–0.35
Lead	[A]

[A] Lead shall not be added to any steel produced for Type B.

TABLE 2
TENSILE REQUIREMENTS

Grade	Type	Tensile Strength, ksi (MPa), min	Yield Strength,[A] ksi (MPa), min	Elongation in 2 in. or 50 mm, min, %
35	B	60 (415)	35 (240)	21
40	B	70 (485)	40 (275)	17

[A] Determined at 0.5% extension under load.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Special Straightness

S1.1 Bars shall be furnished to special straightness tolerance.

S2. Stress Relief Anneal

S2.1 Bars shall be given a stress relief anneal subsequent to all hot and cold mechanical working operations.

S3. Descaling

S3.1 The surface of the bars shall be descaled by pickling or shot blasting. Descaled bars shall be oiled.

SPECIFICATION FOR STEEL BARS, CARBON, HOT-WROUGHT OR COLD-FINISHED, SPECIAL QUALITY, FOR PRESSURE PIPING COMPONENTS

SA-696

[Identical with ASTM Specification A 696-90a (Reapproved 1995)$^{\epsilon 1}$.] 98

1. Scope

1.1 This specification covers hot-wrought and cold-finished special quality carbon steel bars, in straight lengths only, subject to mechanical property requirements and intended for use in manufacturing components for pressure piping and other pressure-containing applications.

98 **1.2** The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

3. Classification

3.1 The bars are furnished in two grades as follows:

3.1.1 *Grade B* — Tensile strength 60 000 psi (415 MPa), min; yield strength 35 000 psi (240 MPa), min.

3.1.2 *Grade C* — Tensile strength 70 000 psi (485 MPa), min; yield strength 40 000 psi (275 MPa), min.

3.2 The bars are intended for machining, welding, hot forming, and threading by machining or cold rolling.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 29/A 29M unless otherwise provided herein.

5. Ordering Information

5.1 Orders for material under this specification should include the following information:

5.1.1 Quantity (weight or number of bars),

5.1.2 Name of material (carbon steel bars),

5.1.3 Condition: hot wrought or cold finished (6.4.1),

5.1.4 Finish (if descaled required, so state) (9.1),

5.1.5 Dimensions (diameter, thickness, width, and length),

5.1.6 Cross section (round, square, hexagon),

5.1.7 ASTM designation and date of issue,

5.1.8 Grade (Tables 1 and 2),

5.1.9 End use, and

5.1.10 Additions to the specification and supplementary requirements, if required.

NOTE — A typical ordering description is as follows: 10 000 lb, Carbon Steel Bars, Hot Wrought, Descaled, 1.000-in. diameter by 10 ft, Round, ASTM A 696 dated _____, Grade B; Supplementary Requirement S1 Straightness 0.125 in. in any 5 ft.

6. Materials and Manufacture

6.1 *Melting Practice* — The steel shall be made by one or more of the following primary processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting using electroslag remelting or vacuum arc remelting. Where secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

6.2 *Deoxidation* — The steel shall be fully killed.

6.3 *Quality* — The bars shall be special quality.

6.4 *Hot or Cold Working:*

6.4.1 The bars shall be hot wrought or cold finished as specified by the purchaser.

6.4.2 Cold-finished bars reduced in cross-section area more than 10% by cold drawing or rolling shall be heat treated as specified in 6.5.2.

6.5 *Heat Treatment:*

6.5.1 Except as provided in 6.5.2, the bars shall be furnished as-hot wrought or as-cold finished.

6.5.2 Cold-finished bars cold worked in excess of 10% (see 6.4.2) shall be stress relief annealed at not less than 1200°F (649°C), normalized, or fully annealed. The specific heat treatment shall be at the option of the manufacturer.

7. Chemical Composition

7.1 The heat analysis shall conform to the requirements for chemical composition specified in Table 1.

7.2 A product analysis of the steel may be made by the purchaser and shall conform to the requirements of Table 1 subject to the product analysis tolerances specified in Specification A 29/A 29M.

8. Tensile Requirements

8.1 *Requirements:*

8.1.1 The material, as represented by the test specimens, shall conform to the tensile requirements specified in Table 2.

8.1.2 A deduction from the percentage of elongation specified in Table 2 of 1.0% shall be made for each 1.0 in. (25.4 mm) of specified diameter over 2.0 in. (51 mm) or fraction thereof to a maximum of 3%.

8.2 *Specimens:*

8.2.1 Tension test specimens shall be taken longitudinally from a position midway between the center and the surface of the bar or as close as practical to this location for small sizes.

8.2.2 When it is impractical to remove specimens in accordance with 8.2.1, they shall be taken in accordance with Test Methods and Definitions A 370.

8.3 *Number of Tests* — One tension test shall be made from each lot. A lot shall consist of all bars of one size from one heat processed at one time and subjected to the same heat treatment when heat treated.

8.4 *Test Methods* — Tension tests shall be made in accordance with Test Methods and Definitions A 370. The yield strength shall be determined by the 0.2% offset or 0.5% extension underload methods.

9. Workmanship, Finish, and Appearance

9.1 *Descaling* — When descaled bars are required, Supplementary Requirement S7 must be specified.

9.2 The bars shall be free of visible pipe and conditioned as necessary to remove injurious surface imperfections.

10. Packaging and Package Marking

10.1 Bars less than 2.0 in. (51 mm) in diameter or thickness shall be tightly banded with a sufficient number of bands of adequate strength to minimize bundle breakage during handling and shipping. Larger sizes shall be packaged in accordance with Specification A 29/A 29M.

10.2 For bars less than 2.0 in. (51 mm) in diameter or thickness, each bundle shall bear a weather resistant tag showing the purchase order number, ASTM designation number and grade, heat number, size, and name of manufacturer.

10.3 Bars 2.0 in. (51 mm) and larger in diameter or thickness shall have the heat number steel stamped on one end.

11. Certification and Test Reports

11.1 A manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the heat analysis and tension test results shall be furnished at the time

of shipment. The report shall include the name of the manufacturer, ASTM designation number and grade, shape, size, and finish.

98 12. Keywords

12.1 pressure piping components; special quality steel bars; steel bars

TABLE 1
CHEMICAL REQUIREMENTS (HEAT ANALYSIS), %

	Grades B and C
Carbon, max [B]	0.32
Manganese, max	1.04
Phosphorus, max	0.035 [A]
Sulfur, max	0.045 [A]
Silicon	0.15 to 0.35
Lead	[A]

[A] Phosphorus, sulfur, or lead, or a combination thereof, shall not be added.

[B] For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to a maximum of 1.35%.

TABLE 2
TENSILE REQUIREMENTS

	Grade B	Grade C
Tensile strength, min ksi (MPa)	60 (415)	70 (485)
Yield strength, min, ksi (MPa)	35 (240)	40 (275)
Elongation in 2.0 in. or 50 mm, min, %	20.0	18.0
Elongation in 8.0 in. or 200 mm, min, % [A]	17.0	15.0

[A] Applicable to bars $1\frac{1}{2}$ in. (38 mm) in diameter tested full size.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirements of the specification itself.

S1. Special Straightness

S1.1 Bars shall be within the tolerances for special straightness.

S2. Stress Relief Anneal

S2.1 Bars shall be stress relief annealed (may be specified for bars that have been ordered to special straightness tolerance).

S3. Surface Quality

S3.1 Bars shall be produced to special surface quality requirements which shall be negotiated between purchaser and supplier.

S4. Special Internal Soundness

S4.1 Bars shall be produced with special internal soundness to be verified by one or more macro-etch samples. Acceptance limits shall be negotiated between purchaser and seller.

S5. Fine Grain Practice

S5.1 The steel shall conform to the fine austenitic grain size requirement of Specification A 29/A 29M.

S6. Restricted Size Tolerances for Hot-Wrought Bars

S6.1 Bars shall be furnished with tolerances on dimensions more restrictive than specified in Specification A 29/A 29M. Tolerance requirements to apply shall be negotiated between purchaser and manufacturer.

S7. Descaling

S7.1 Bars shall be furnished descaled and oiled.

SPECIFICATION FOR STEEL CASTINGS, GENERAL REQUIREMENTS, FOR PRESSURE-CONTAINING PARTS

SA-703/SA-703M

(Identical with ASTM Specification A 703/A 703M-94.)

1. Scope

1.1 This specification covers a group of common requirements which, unless otherwise specified in an individual specification, shall apply to steel castings for pressure-containing parts under each of the following ASTM specifications:

Title of Specification	ASTM Designation
Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service	A 216/A 216M
Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts Suitable for High-Temperature Service	A 217/A 217M
Steel Castings, Austenitic, for High-Temperature Service	A 351/A 351M
Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts Suitable for Low-Temperature Service	A 352/A 352M
Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service	A 389/A 389M
Steel Castings Suitable for Pressure Service	A 487/A 487M

1.2 This specification also covers a group of supplementary requirements which may be applied to the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 In case of conflict between the requirements of the individual specification and this general specification, the former shall prevail.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 703 and SI units for material ordered to Specification A 703M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding for High-Temperature Service

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts Suitable for High-Temperature Service

A 351/A 351M Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure Containing Parts

A 352/A 352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts Suitable for Low-Temperature Service

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 389/A 389M Specification for Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 487/A 487M Specification for Steel Castings Suitable for Pressure Service

A 488/A 488M Practice for Steel Castings, Welding, Qualification of Procedures and Personnel

A 609/A 609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 800/A 800M Practice for Steel Casting, Austenitic Alloy, Estimating Ferrite Content Thereof
A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination
A 919 Terminology Relating to Heat Treatment of Metals
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 94 Guide for Radiographic Testing
E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
E 165 Practice for Liquid Penetrant Inspection Method
E 186 Reference Radiographs for Heavy-Walled (2 to 4 ½ in. [51 to 114-mm] Steel Castings
E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels
E 280 Reference Radiographs for Heavy-Walled (4-½ to 12 in. [114 to 305-mm]) Steel Castings
E 340 Method for Macroetching Metals and Alloys
E 446 Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness
E 709 Practice for Magnetic Particle Examination

2.2 *ANSI Standard:*
B16.5 Steel Pipe Flanges and Flanged Fittings

2.3 *ASME:*
ASME Boiler and Pressure Vessel Code, Section III, NB-2546

2.4 *Standards of the Manufacturer's Standardization Society of the Valve and Fitting Industry:*
MSS SP 53 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Dry Powder Magnetic Particle Inspection Method)
MSS SP 54 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Radiographic Inspection Method)

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Test Methods and Definitions A 370 and Terminology A 919 are applicable to this specification and those listed in 1.1.

3.1.2 *chaplet, n*—a chaplet is a metallic support placed in a mold cavity to maintain the spacing between a core and the mold.

3.1.3 *heat, n*—all the molten metal poured from a single furnace or all the molten metal from two or more furnaces poured into single ladle or casting prior to the replenishing of the furnace(s).

3.1.4 *internal chill, n*—an internal chill is a metallic device placed in a mold cavity to increase the rate of heat removal at that location.

4. Materials and Manufacture

4.1 *Melting Process*—The steel shall be made by open-hearth or electric-furnace process, with or without separate refining such as argon-oxygen-decarburization (AOD), unless otherwise designated by the individual specification.

4.2 *Heat Treatment*—Ferritic and martensitic steel shall be cooled after pouring to provide substantially complete transformation of austenite prior to heat treatment to enhance mechanical properties.

5. Chemical Composition

5.1 *Chemical Analysis*—Chemical analysis of materials covered by this specification shall be in accordance with Test Methods A 751.

5.2 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified. The analysis shall be made from a test sample preferably taken during the pouring of the heat. When drillings are used, they shall be taken not less than ¼ in. [6.4 mm] beneath the surface. The chemical composition thus determined shall be reported to the purchaser, or his representative, and shall conform to the requirements in the individual specification for the grade being poured.

5.3 *Product Analysis*—A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Due to the possibility of decarburization, carbon and alloy steel samples for carbon analysis shall be taken no closer than ¼ in. [6.4 mm] to a cast surface except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in the appllicable specification for the grade involved, or shall be subject to rejection

the purchaser, except that the chemical composition determined for carbon and low-alloy steel castings may vary from the specified limits by the amounts shown in Table 1. The product analysis tolerances of Table 1 are not applicable as acceptance criteria for heat analysis by the casting manufacturer.

5.4 *Unspecified Elements*—When chemical analysis for elements not specified for the grade ordered is desired, Supplementary Requirement S1 may be specified.

5.5 The substitution of a grade or composition different from that specified by the purchaser is prohibited.

6. Mechanical Test Methods

6.1 All mechanical tests shall be conducted in accordance with Test Methods and Definitions A 370.

7. Tensile Requirements

7.1 One tension test shall be made from each heat, and shall conform to the tensile requirements specified. Test bars shall be poured in special blocks from the same heat as the castings represented, except that for investment castings the test specimens shall be cast in the same type of mold as the castings.

7.2 The bar from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents.

7.3 Test specimens may be cut from heat treated castings, at the producer's option, instead of from test bars.

7.4 *Investment Castings*—For investment castings, the specimens may be cast to shape or machined from blocks to dimensions in accordance with Test Methods and Definitions A 370 or the ICI bar shown in Fig. 1.

7.5 *Other Castings*—Unless otherwise specified by the purchaser, test coupons may be cast integrally with the castings or as separate blocks in accordance with Fig. 1 and Table 2, with Fig. 2, or with Fig. 3, except when Supplementary Requirement S26 is specified. The test coupon in Fig. 4 shall be employed only for austenitic alloy castings with cross sections less than $2\frac{1}{2}$ in. [63.5 mm]. Tension test coupons shall be machined or ground to the form and dimension shown in Fig. 6 of Test Methods and Definitions A 370.

7.6 If any specimen shows defective machining or develops flaws, it may be discarded and another substituted from the same heat.

7.7 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice E 29 to the nearest 500 psi [5 MPa] for yield and tensile strength and to the nearest 1% for elongation and reduction of area.

8. Repair by Welding

8.1 Repair by welding shall be in accordance with the requirements of individual specification using procedures and welders qualified in accordance with Practice A 488/A 488M.

9. Flanges

9.1 When a flange from a flanged casting is removed to make a weld end casting, discontinuities may be observed that would not have been detrimental in a flanged casting. The disposition of the casting shall be subject to agreement between the purchaser and manufacturer.

10. Quality

10.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

10.2 The castings shall not be peened, plugged, or impregnated to stop leaks.

10.3 Internal chills and chaplets may be used in the manufacture of castings. However, the chills, chaplets, and affected cast material must be completely removed.

11. Hydrostatic Tests

11.1 Each casting shall be tested after machining to the hydrostatic shell test pressures prescribed in ANSI B16.5 for the applicable steel rating for which the casting is designed. Casting shall show no leaks. Cast-

ings ordered for working pressures other than those in the standard ANSI ratings, or those listed for which test pressures are not specified by ANSI B16.5, shall be tested at a pressure agreed upon between manufacturer and the purchaser.

11.2 It is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work or machining has been performed on the casting. Castings ordered in the rough state for final machining by the purchaser may be tested hydrostatically prior to shipment by the manufacturer at pressures to be agreed upon with the purchaser. However, the foundry is responsible for the satisfactory performance of the castings under the final test required in 10.1.

12. Workmanship, Finish, and Appearance

12.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser. When the patterns is supplied by the purchaser, the dimensions of the castings shall be as predictated by the pattern unless otherwise agreed upon.

12.2 Machined welding ends shall be suitably protected against damage during shipping.

13. Retests

13.1 If the results of the mechanical tests for any heat, lot, or casting do not conform to the requirements specified, retests are permitted as outlined in Test Methods and Definitions A 370. At the manufacturer's option, castings may be reheat-treated and retested. When castings are reheat-treated, they may not be reaustenitized more than three times without the approval of the purchaser. Testing after reheat treatment shall consist of the full number of specimens taken from locations complying with the specification or order.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections, with the exception of product analysis (5.2), shall be made at the place of manufacture unless otherwise agreed.

15. Rejection and Rehearing

15.1 Any rejection based on test reports shall be reported to the manufacturer within 30 days from the receipt of the test reports by the purchaser.

15.2 Material that shows unacceptable discontinuities as determined by the acceptance standards specified in the order subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified within 30 days after discovery of the rejectable condition.

15.3 Samples that represent rejected material shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

16. Certification

16.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification (including year of issue) and was found to meet the requirements.

16.2 As applicable, the certification shall also include:

16.2.1 Material specification and grade,

16.2.2 Pattern number,

16.2.3 Heat number or serial number traceable to a heat number,

16.2.4 Chemical analysis of the heat,

16.2.5 Mechanical property results required by the specification and supplementary requirements specified in the purchase order,

16.2.6 Statement of satisfactory inspection, visual, and nondestructive testing specified in the purchase order,

16.2.7 Manufacturer's name, and

16.2.8 Additional purchase order requirements.

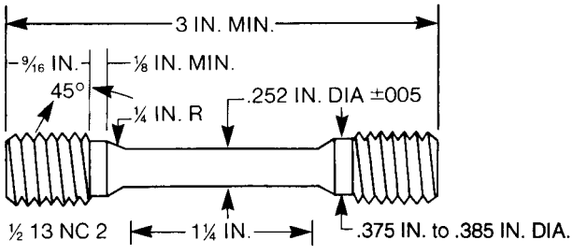
16.3 A signature is not required on the certification. However, the document shall clearly identify the organization submitting the certification. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

17. Product Marking

17.1 Castings shall be marked for material identification with the grade symbols (WCB, WC9, CF8M, etc.). In addition, heat numbers, or serial numbers that are traceable to heat numbers, shall be marked on all pressure-containing castings individually weighing 50 lb [22.7 kg] or more. Pressure-containing castings weighing less than 50 lb [22.7 kg] shall be marked with either the heat number or a lot number that will identify the casting as to the month in which it was poured. Marking shall be in such position as not to injure the usefulness of the casting.

17.2 On castings for which impact property requirements are specified, stamped markings using low-stress stamps shall be on a raised pad when such pad can be made a part of the castings.

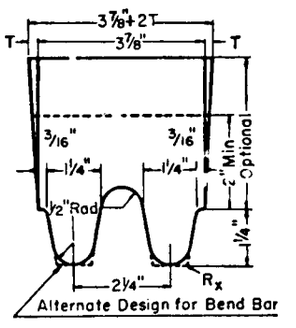
17.3 Castings shall be marked with the manufacturer's identification or symbol except when other provisions have made between the manufacturer and purchaser.



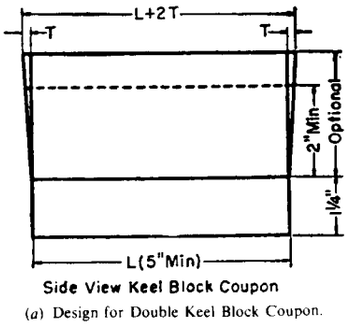
Metric Equivalents

in.	0.005	1/8	0.252	0.375	0.385	9/16	1 1/4	3
[mm]	[0.15]	[3]	[6.40]	[9.50]	[9.75]	[15]	[30]	[75]

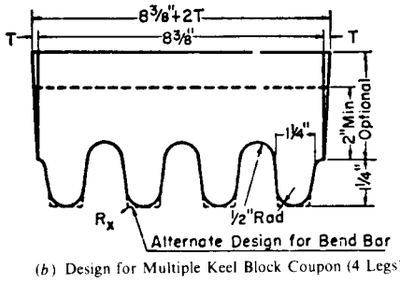
FIG. 1 DESIGN AND DIMENSIONS OF THE ICI TEST BAR

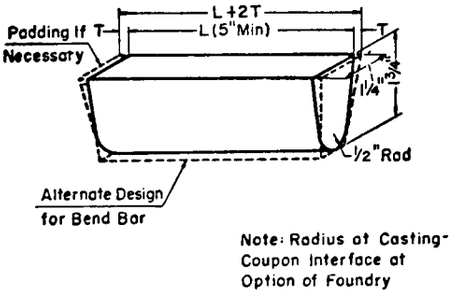


(*b*) Design for Multiple Keel Block Coupon (4 Legs).



(*a*) Design for Double Keel Block Coupon.



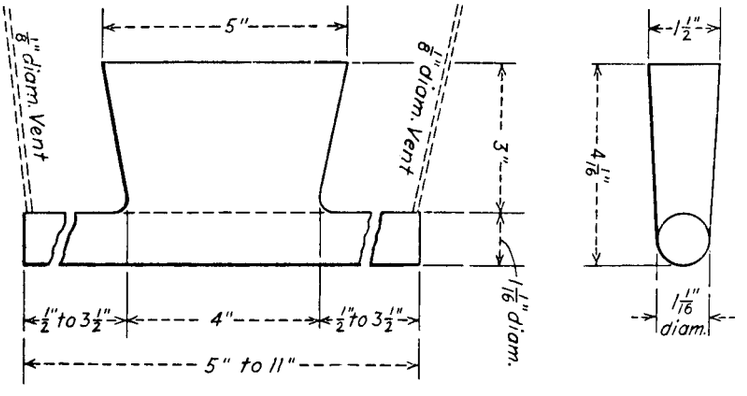


(*c*) Design for "Attached" Coupon.

Metric Equivalents

in.	3/16	½	1¼	1¾	2	2¼	3⅞	5	8⅛
mm	4.8	13	32	45	51	57	98	127	213

FIG. 2 TEST COUPONS FOR CASTINGS (SEE TABLE 2 FOR DETAILS OF DESIGN)

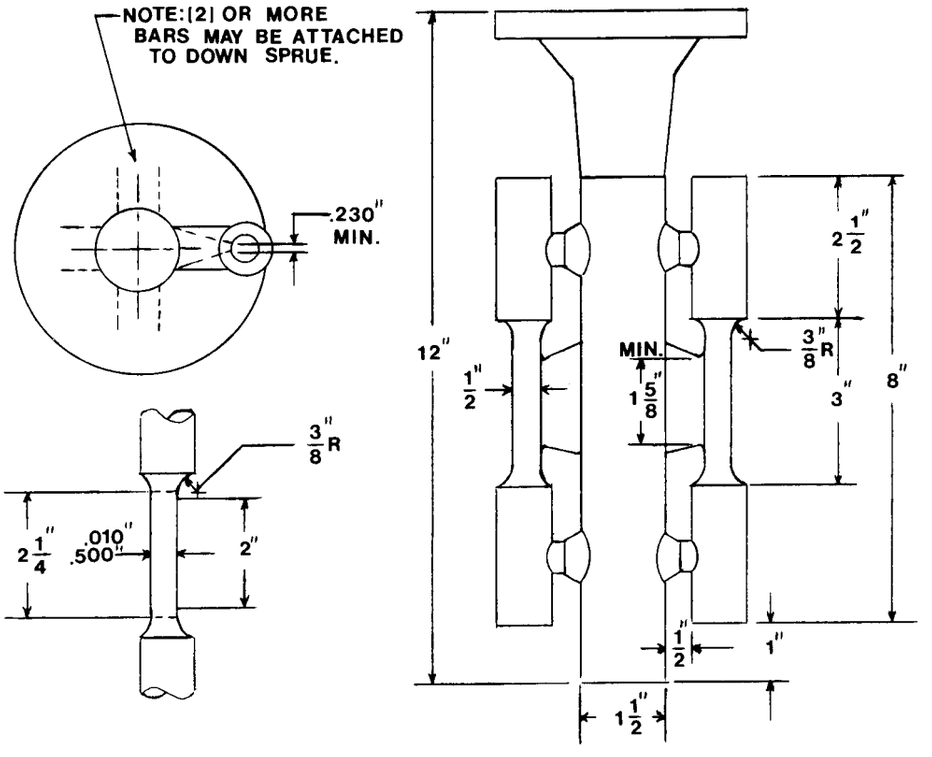


Metric Equivalents

in.	mm	in.	mm
⅛	3.2	3½	88.9
½	12.7	4	101.6
1 1/16	27.0	4 1/16	103.2
1½	38.1	5	127.0
3	76.2	11	279.4

NOTE—Pour through head; cover molten head with powdered charcoal, coke dust, etc., immediately after pouring, in order to keep head fluid as long as possible.

FIG. 3 TEST BLOCK FOR TENSION TEST SPECIMEN



Metric Equivalents

in.	mm	in.	mm
0.010	0.254	1⅝	41.275
0.230	5.842	2¼	57.15
⅜	9.525	2½	63.5
½	12.7	3	76.2
1	25.4	8	203.2
1½	38.1	12	304.8

NOTE—Coupons produced in this manner are suitable for austenitic alloys only. The mold may be preheated for pouring to produce a sound coupon.

FIG. 4 CAST-TO-SHAPE TEST COUPON FOR TENSION TEST SPECIMEN

TABLE 1
PRODUCT ANALYSIS TOLERANCES FOR CARBON AND LOW-ALLOY STEELS

Element	Range[A]	Tolerances[B,C] over max or under min, Limit, %
Carbon (C)	up to 0.65%	0.03 × % C_L + 0.02
	above 0.65%	0.04%
Manganese (Mn)	up to 1%	0.08 × % Mn_L + 0.01
	above 1%	0.09
Silicon (Si)	up to 0.60%	0.22 × % Si_L − 0.01
	above 0.60%	0.15%
Phosphorus (P)	all	0.13 × % P_L + 0.005
Sulfur (S)	all	0.36 × % S_L + 0.001
Nickel (Ni)	up to 2%	0.10 × % Ni_L + 0.03
	above 2%	0.25%
Chromium (Cr)	up to 2%	0.07 × % Cr_L + 0.04
	above 2%	0.18%
Molybdenum (Mo)	up to 0.6%	0.04 × % Mo_L + 0.03
	above 0.6%	0.06%
Vanadium (V)	up to 0.25%	0.23 × % V_L + 0.004
	above 0.25%	0.06%
Tungsten (W)	up to 0.10%	0.08 × % W_L + 0.02
	above 0.10%	0.02%
Copper (Cu)	up to 0.15%	0.18 × % Cu_L + 0.02
	above 0.15%	0.05%
Aluminum (Al)	up to 0.10%	0.08 × % Al_L + 0.02
	above 0.10%	0.03%

[A] The range denotes the composition limits up to which the tolerances are computed by the equation, and above which the tolerances are given by a constant.

[B] The subscript $_L$ for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit, if applicable, respectively. Examples of computing tolerances are presented in the footnote *C*.

[C] To compute the tolerances, consider the manganese limits 0.50 – 80% of Grade WC4 of Specification A 217/A 217M. According to Table 1, the maximum permissible deviation of a product analysis below the lower limit 0.50 is 0.05% = (0.08 × 0.50 + 0.01). The lowest acceptable product analysis of Grade WC4, therefore, is 0.45%. Similarly, the maximum permissible deviation above the upper limit of 0.80% is 0.074% = (0.08 × 0.80 + 0.01). The highest acceptable product analysis of Grade WC4, therefore, is 0.874. For Grade WCC of Specification A 216/A 216M, the maximum manganese content is 1.20% if the carbon content is 0.20%. In this case, the highest acceptable product analysis is 1.29 = (1.20 + 0.09).

TABLE 2
DETAILS OF TEST COUPON DESIGN FOR CASTING (SEE FIG. 2)

NOTE 1 — *Test Coupons for Large and Heavy Steel Castings:* The test coupons in Fig. 2 are to be used for large and heavy steel castings. However, at the option of the foundry the cross-sectional area and length of the standard coupon may be increased as desired.

NOTE 2 — *Bend Bar:* If a bend bar is required, an alternate design (as shown by dotted lines in Fig. 2) is indicated.

Leg Design [125 mm]		Riser Design	
1. *L* (length)	A 5 in. [125 mm] minimum length will be used. This length may be increased at the option of the foundry to accommodate additional test bars (see Note 1).	1. *L* (length)	The length of the riser at the base will be the same as the top length of the leg. The length of the riser at the top therefore depends on the amount of taper added to the riser.
2. End taper	Use of and size of end taper is at the option of the foundry.	2. Width	The width of the riser at the base of a multiple-leg coupon shall be *n,* $2\frac{1}{4}$ [57 mm] — $\frac{5}{8}$ [16 mm] where *n* equals the number of legs attached to the coupon. The width of the riser at the top is therefore dependent on the amount of taper added to the riser.
3. Height	$1\frac{1}{4}$ in. [32 mm]		
4. Width (at top)	$1\frac{1}{4}$ in. [32 mm] (see Note 1).		
5. Radius (at bottom)	$\frac{1}{2}$ in. [13 mm], max		
6. Spacing between legs	A $\frac{1}{2}$ in. [13 mm] radius will be used between the legs.		
7. Location of test bars	The tensile, bend, and impact bars will be taken from the lower portion of the leg (see Note 2).	3. *T* (riser taper)	Use of and size is at the option of the foundry.
8. Number of legs	The number of legs attached to the coupon is at the option of the foundry providing they are equispaced according to item 6.	Height	The minimum height of the riser shall be 2 in. [51 mm]. The maximum height is at the option of the foundry for the following reasons: (*a*) Many risers are cast open, (*b*) different compositions may require variation in risering for soundness, (*c*) different pouring temperatures may require variation in risering for soundness.
9. R_s	Radius from 0 to approximately $\frac{1}{16}$ in. [2 mm].		

SUPPLEMENTARY REQUIREMENTS

The following standardized supplementary requirements are for use when desired by the purchaser and when allowed by and listed in the individual specifications. They shall not apply unless specified in the order, in which event the specified tests shall be made by the manufacturer before shipment of the castings.

S1. Unspecified Elements

S1.1 Limits may be established for elements not specified for the grade ordered by agreement between the manufacturer and purchaser. The results of the analysis for the agreed-upon elements shall be reported.

S2. Destruction Tests

S2.1 Purchaser may select representative castings from each heat and cut up and etch, or otherwise prepare, the sections for examination for internal defects. Should injurious defects be found that evidence unsound steel or faulty foundry technique, all the castings made from that particular pattern, heat, and heat treatment charge may be rejected. All the rejected castings including those cut up, shall be replaced by the manufacturer without charge.

S3. Bend Test

S3.1 One bend test shall be made from a test coupon from each heat in accordance with Test Methods and Definitions A 370, and shall be machined to 1 by $\frac{1}{2}$ in. [25 by 13 mm] section with corners rounded to a radius not over $\frac{1}{16}$ in. [1.6 mm].

S3.2 The specimen shall withstand being bent longitudinally at room temperature through an angle of 90° about a pin the diameter of which shall be the specimen thickness for carbon steel, and 1 in. [25 mm] for other steels. The specimen shall show no cracks on the outside of the bent portion of the specimen.

S3.3 Bend test specimens may be cut from heat-treatment castings instead of from test bars when agreed upon between manufacturer and purchaser.

S3.4 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same heat.

S4. Magnetic Particle Inspection

S4.1 Castings shall be examined for surface and near surface discontinuities by magnetic particle inspection. The examination shall be in accordance with Practice E 709; and types and degrees of discontinuities considered shall be judged by the Reference Photographs E 125. Extent of examination, time of examination, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification which may be used as a basis for such agreement is MSS SP 53.

S4.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S5. Radiographic Inspection

S5.1 Castings shall be examined for internal defects by means of X rays or gamma rays. The procedure shall be in accordance with Guide E 94 and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 446, E 186, or E 280. Extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification that may be used as a basis for such agreement is MSS SP 54.

S5.2 Radiographic examination of castings may be performed before or after any heat treatment.

S5.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S6. Liquid Penetrant Inspection

S6.1 Castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The examination shall be in accordance with Practice E 165. Areas to be inspected, time of inspection, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. In the

absence of available reference standards for liquid penetrant inspection, indications may be compared with Reference Photographs E 125 or referenced to ASME Section III, NB-2546.

S6.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S7. Ultrasonic Inspection

S7.1 Castings shall be examined for internal defects by means of ultrasonic inspection. The inspection procedure shall be in accordance with Practice A 609/A 609M. Extent of examination, methods of test, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S7.2 Ultrasonic examination of castings shall be performed after at least one heat treatment above the critical temperature range but need not be repeated after subsequent heat treatment.

S7.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S8. Charpy Impact Test

S8.1 Charpy impact test properties shall be determined on each heat from a set of three charpy V-notch specimens made from a test coupon in accordance with Test Methods and Definitions A 370, and tested at a test temperature agreed upon by the manufacturer and purchaser. The acceptance requirements shall be either energy absorbed, lateral expansion, or percent shear area, or all three, and shall be that agreed upon by the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S8.2 *Absorbed Energy*—Average energy value of three specimens shall be not less than specified, with not more than one value permitted to fall below the minimum specified and no value permitted below the minimum specified for a single specimen.

S8.3 *Lateral Expansion*—Lateral expansion value shall be agreed upon by the manufacturer and purchaser.

S8.4 *Percent Shear Area*—Percent shear area shall be agreed upon by the manufacturer and purchaser.

S9. Drop Weight Tests

S9.1 Drop weight test properties shall be determined from each heat by preparing and testing either Type P1, P2, or P3 specimens in accordance with Test Method E 208. The crack starter weld shall be deposited on the surface of the specimen that was nearest to the casting surface. Each test shall consist of at least two specimens tested at a temperature agreed upon by the manufacturer and purchaser. Each specimen shall exhibit "no break" performance.

S10. Examination of Weld Preparation

S10.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the inspection method specified for the casting. The method of performing magnetic particle or liquid penetrant examination shall be in accordance with Practice E 709 or Practice E 165. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E 125, of Degree 2 in sections up to 2 in. [50 mm] thick and of Degree 3 in sections over 2 in. [50 mm] thick shall be acceptable.

S12. Prior Approval of Major Weld Repairs

S12.1 Major weld repairs shall be subject to the prior approval of the purchaser.

S13. Hardness Test

S13.1 A hardness test shall be made in accordance with Test Methods and Definitions A 370. The test location and the hardness requirements shall be agreed upon between the manufacturer and the purchaser.

S14. Tension Test from Each Heat and Heat Treatment Charge

S14.1 One tension test shall be made for each heat and heat treatment charge.

S15. Quench and Temper Heat Treatment

S15.1 The castings shall be quenched and tempered. Castings so treated shall be marked QT.

S17. Tension Test from Castings

S17.1 In addition to the tensile test required in Section 6, test material shall be cut from heat treated castings. The mechanical properties and location for the test material shall be agreed upon by the manufacturer and purchaser.

S18. Tension Test for Castings Each Weighing 10 000 lb [4500 kg] or More

S18.1 Two tensile tests shall be made for each casting. The test specimens shall be prepared in accordance with Section 6. The location of the test bars shall be agreed upon by the manufacturer and purchaser.

S20. Weld Repair Charts

S20.1 Major weld repairs shall be documented by means of sketches or photographs or both showing the location and major dimensions of cavities prepared for welding. Documentation shall be submitted to the purchaser at the completion of the order.

S20.2 A weld repair shall be considered major when it is made to correct leakage on hydrostatic testing, or when the depth of the cavity prepared for welding exceeds 20% of the actual wall thickness or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [65 cm^2].

S21. Heat Treatment Furnace Record

S21.1 A heat treatment chart showing time and temperature shall be prepared and be available for inspection by the purchaser.

S22. Heat Treatment

S22.1 Test specimens shall be heat-treated together with the castings they represent. Heat-treated specimens shall be tested and shall meet the tensile and impact properties specified.

S22.2 The remaining test specimens from Supplementary Requirement S22.1 representing the casting shall be treated thermally after the final (foundry) heat-treatment to simulate heat-treatments below the critical temperature which the casting may receive during fabrication, and then tested for mechanical properties. Time, temperature and cooling rate shall be as stated in the order. In the case of postweld heat-treatment, the total time at temperature or temperatures for the test material shall be at least 80% of the total time at temperature or temperatures during actual postweld heat-treatment of the fabrication of which the casting or castings are a part. The total time at temperature or temperatures for the test material may be performed in a single cycle. When this Supplementary Requirement is specified, the welding qualification test metal must be processed in the same manner.

S23. Macroetch Test

S23.1 Apply Supplementary Requirement S1 for the spectrographic determination and reporting of the total residual aluminum content of all heats of ferritic and martensitic steels subjected to this macroetch test.

S23.2 When the heat analysis indicates a total residual aluminum content in excess of 0.08%, the manufacturer shall etch a cross section of the casting with the heaviest section for which this supplementary requirement is invoked, or a coupon attached to that heaviest section or an area directly under a riser (Note S23.1). Cross sections, from a separately cast test block from the same heat and of a thickness representative of the heaviest section of castings purchased under this supplementary requirement, may also be used for macroetch testing. The etching shall be performed on the selected section after its heat-treatment, that is, after annealing, normalizing, or quenching and tempering following the initial cooling of the steel below the transformation range.

NOTE S23.1—High strength martensitic castings, in particular, may be damaged beyond use if the etch is applied directly to the casting.

S23.3 The preparation of the surface and the macroetching procedure with solution No. 1 (1:1 HCl) of Table 5 in Test Method E 340 shall be followed. The resulting etched surface shall be compared and rated with the reference photographs in Fig. S23.1 depicting 10 levels of severity of intergranular network structures indicative of the presence of aluminum nitride, or other constituents prone toward precipitating at grain boundaries during solidification and subsequent cooling. Table S23.1 relates the severity levels shown in these photographs with specific delineation widths and percent of boundary outlining in the etched structures.

S23.4 Castings represented by etched structures exhibiting a network rating in excess of Severity Level 4 shall be considered unacceptable until further evaluations are completed. The acceptability of individual castings may be determined by etching sections of each casting to

ascertain the network severity level. Disposition of unacceptable castings shall be a matter of agreement between the manufacturer and purchaser. Those castings exhibiting etched severity levels greater than four may be further evaluated by any of the following agreed upon methods:

S23.4.1 Fracture testing to determine the amount of "rock candy" structure.

S23.4.2 Mechanical testing (bend, tensile, etc.) to determine the ductility characteristics.

S23.4.3 Weld testing to determine crack susceptibility in the heat-affected zone of a circular groove welded with cellulose coated electrodes.

S23.5 Alternatively, by agreement, it is permissible to subject castings from an unacceptable heat to a high temperature solution treatment prior to the normal production heat-treatment and subsequently macroetch test each casting.

S23.6 Heavy section castings (Note S23.2) whose configurations are amenable to the attachment of test coupons representative of the section thickness involved and from which standard 0.505 in. [12.827 mm] diameter tension specimens may be machined are exempt from this macroetch test if the results of the tension test on the coupon after heat-treatment of the casting meet the minimum requirements specified for the grade of steel involved.

NOTE S23.2—For purposes of this supplementary requirement, a heavy section casting is defined as one having a wall thickness of 1½ in. (37 mm) or greater in combination with a casting weight of at least 1000 lb (455kg).

S24. Specified Ferrite Content Range

S24.1 The chemical composition of the heat shall be controlled such that the ferrite content, as determined by the chemical composition procedure of Practice A 800/A 800M, shall be in conformance with the specified ferrite content range.

S24.2 The specified ferrite content range shall be as agreed upon between the manufacturer and the purchaser. The minimum specified ferrite content range shall be 10% with the minimum ferrite content being no lower than the percent necessary to achieve the minimum mechanical properties required for the alloy.

S24.3 Should the purchaser wish to have the ferrite content determined by either magnetic response or metallographic methods, the purchaser should impose supplementary requirement S1 or S2 of Practice A 800/A 800M.

S25. Heat Treatment Certification

S25.1 Heat treatment temperature and cycle times shall be shown on the certification report.

S26. Alternate Tension Test Coupons and Specimen Locations for Castings (in-lieu of Test Bars Poured from Special Blocks)

S26.1 Test blocks may be cast integrally with the castings or as separate blocks. Test blocks shall be heat-treated together with the castings they represent.

S26.2 The casting thickness, *T*, is the maximum thickness of the pressure containing wall of the casting exclusive of padding added for directional solidification, flanges, appendages, and sections designated by the designer as noncritical. The order, inquiry, and drawing shall designate what the test dimension, *T*, is for the casting.

S26.3 One of the following shall apply:

S26.3.1 The longitudinal centerline of the test specimen shall be taken at least ¼ *T* from the *T* dimension surface and all of the gage length must be at least 1*T* from any other heat-treated surface, exclusive of the surface opposite the *T* dimension surface. (See Fig. S26.1(a).) For cylindrical castings, the longitudinal centerline of the specimens shall be taken at least ¼ *T* from the outside or inside and all of the gage length must be at least *T* from the as-heat-treated end. (See Fig. S26.1(b).)

S26.3.2 For ferritic and martensitic castings, partial severing of test blocks prior to final heat treatment is permitted.

S26.3.3 Where separately cast test coupons are used, the dimension shall shall not be less than 3*T* by 3*T* by *T* and each specimen shall meet the requirements of S26.3.1, except that when *T* exceeds 5 in. (125 mm), the dimension may be 15 by 15 by 5 in. (375 by 375 by 125 mm), by agreement between the manufacturer and the purchaser. The test coupon shall be of the same heat of steel and shall receive substantially the same casting practices as the production casting it represents. Centrifugal castings may be represented by statically cast coupons. (See Fig. S26.2.)

S26.3.4 When agreed upon between the manufacturer and the purchaser, castings that are cast or ma-

chined to essentially the finished configuration prior to heat-treatment shall have test specimens removed from a prolongation or other stock on the casting at a location below the nearest heat-treated surface indicated on the order. The specimen location shall be at a distance below the nearest heat-treated surface equivalent to at least the greatest distance that the indicated high-tensile-stress surface will be from the nearest heat-treated surface and a minimum of twice this distance from a second heat-treated surface, except that the test specimens shall be no nearer than $\frac{3}{4}$ in. (19 mm) to a heat-treated surface and $1\frac{1}{2}$ in. (38 mm) from a second heat-treated surface. (See Fig. S26.3.)

S26.3.5 Where specimens are to be removed from the body of quenched and tempered castings, either the requirements of S26.3.1 shall be met or a steel thermal buffer pad or thermal insulation or other thermal barriers shall be used during heat-treatment. Steel thermal buffer pads shall be a minimum of *T* by *T* by 3*T* in length and shall be joined to the casting surface by a partial penetration weld completely sealing the buffered surface. Test specimens shall be removed from the casting in a location adjacent to the center third of the buffer pad. They shall be located at a minimum distance of $\frac{1}{2}$ in. (13 mm) from the buffered surface and $\frac{1}{4}T$ from other heat-treated surfaces (see Fig. S26.4). When thermal insulation is used, it shall be applied adjacent to the casting surface where the test specimens are to be removed. The producer shall demonstrate that the cooling rate of the test specimen location is no faster than that of specimens taken by the method described in S26.3.1.

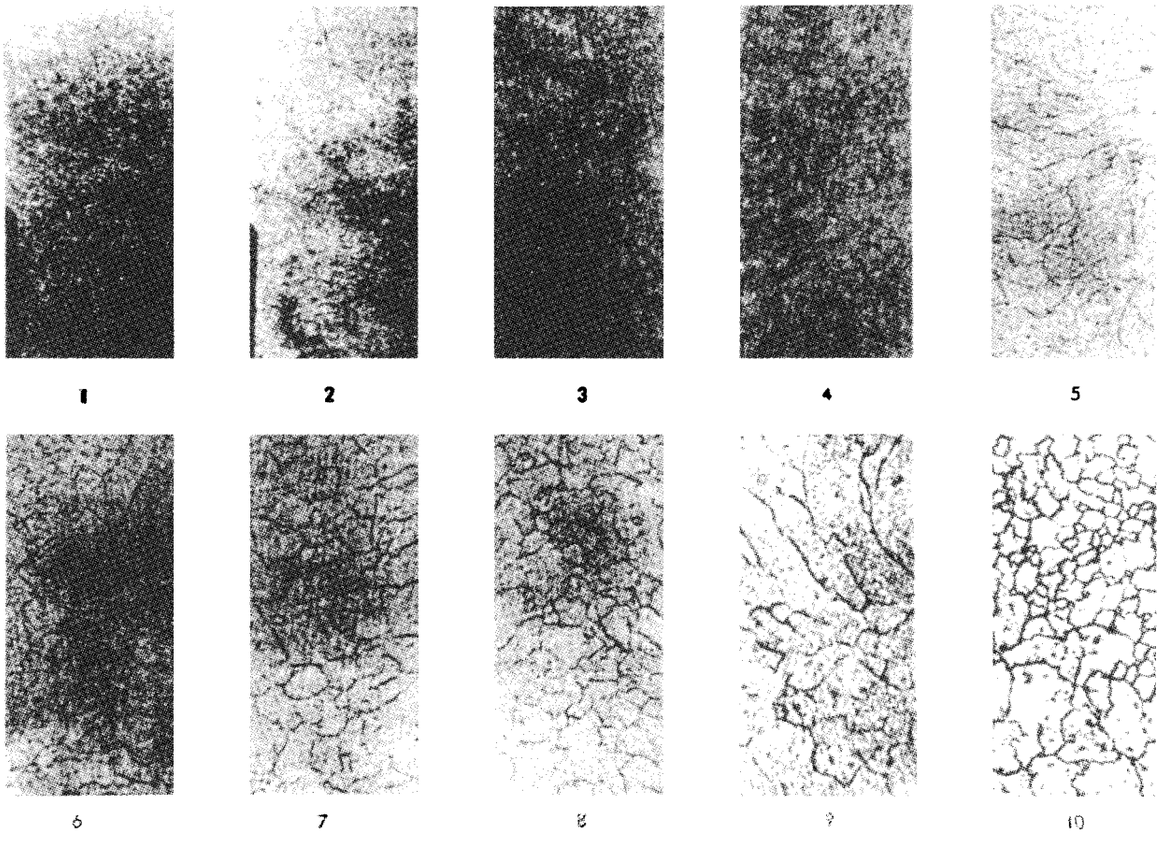
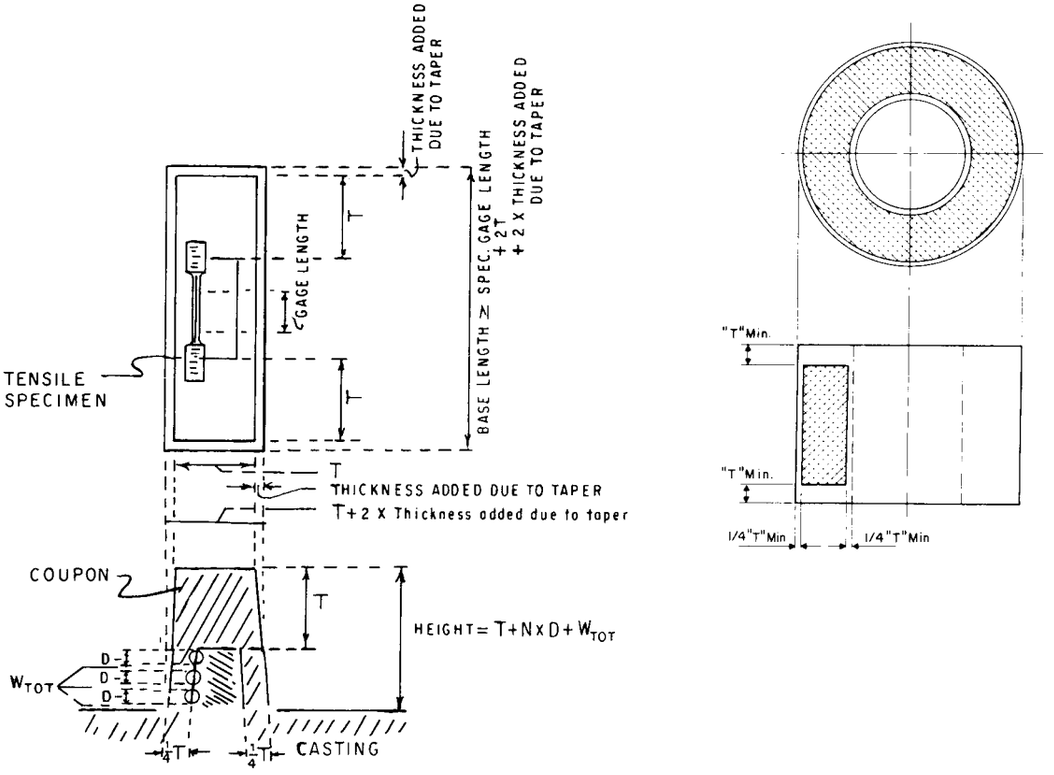


FIG. S23.1 REFERENCE PHOTOGRAPHS OF MACROETCHED CAST STEEL



Minimum length of the base — Specimen gage length + 2x*T* + 2*x* the thickness due to the taper.
Minimum length of the base — *T* + 2*x* the thickness added due to the taper.
Minimum height — *T* + *NxD* + W_{tot}.

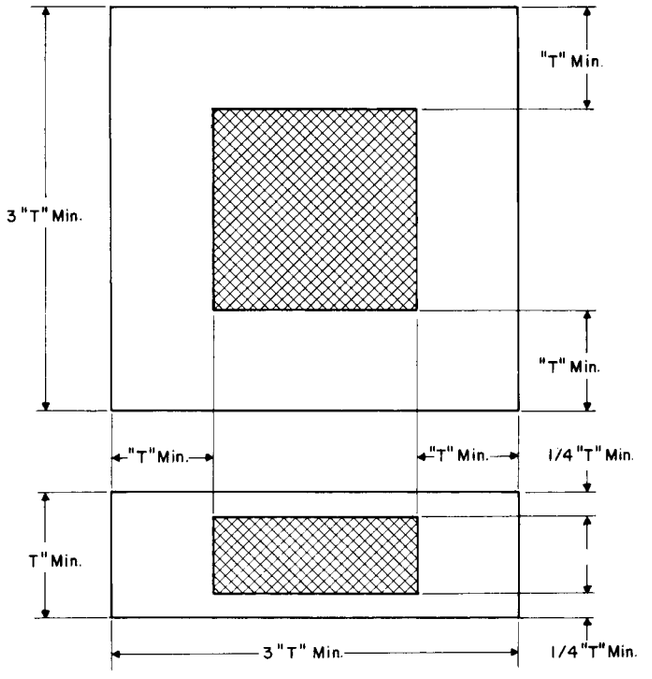
The taper is to be selected by the producer for ease of drawing the pattern from the mold.

where:

N = number of specimens to be cut from one side of the coupon,
D = diameter of the specimens, and
W_{tot} = total width of metal required to remove the coupon from the casting, and to machine specimens from the coupon.

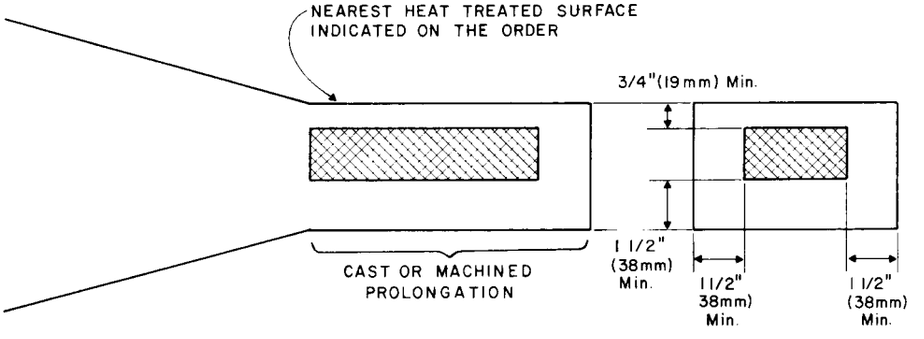
NOTE—Longitudinal axis and gage length of test specimen must be within shaded zone.

FIG. S26.1 SPECIMEN FROM CASTING



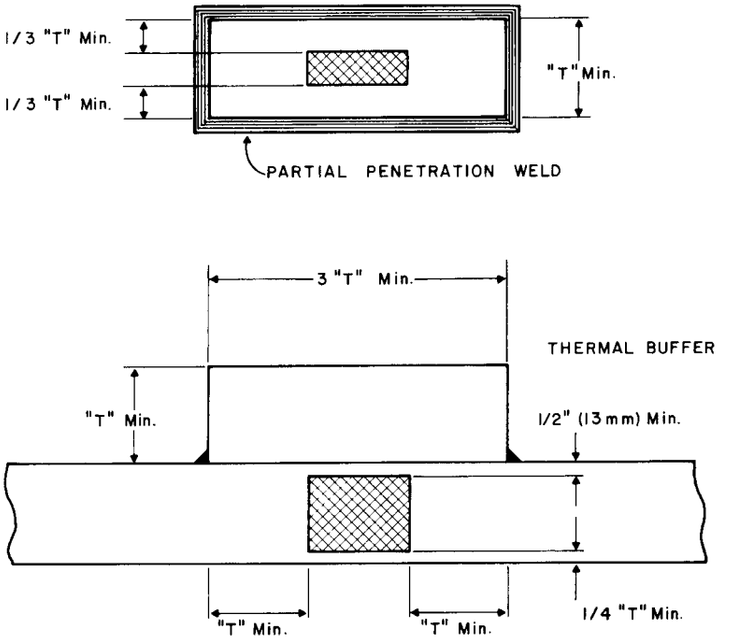
NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S26.2 SEPARATELY CAST BLOCK



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S26.3 PROLONGATION TEST SPECIMEN



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S26.4 THERMAL BUFFER PADS

TABLE S23.1
DESCRIPTIVE DATA APPLICABLE TO NETWORK STRUCTURES SHOWN IN FIGURE S23.1

NOTE — These ratings are based on the physical width and continuity of the precipitate pattern developed by the acid etchant on the primary austenitic grain boundaries of the cast steel. Supplementary testing is normally conducted to determine the final disposition of castings with ratings of 5 or greater.

Rating	Delineation Width, in.	Boundary Outline, %
1	Fine–0.001	20
2	Fine–0.001	40
3	Fine–0.001	60
4	Fine–0.002	80
5	Fine–0.002	100
6	Medium–0.005	100
7	Heavy–0.010	100
8	0.020	100
9	1/32	100
10	1/16	100

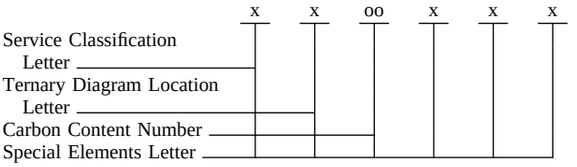
APPENDIX

(Nonmandatory Information)

X1. ALLOY DESIGNATIONS FOR CAST STAINLESS STEELS

X1.1 Cast stainless steels are usually specified on the basis of composition using the alloy designation system established by the Alloy Casting Institute (ACI). The ACI designations, for example, CF8M, have been adopted by ASTM and are preferred for cast alloys over the designations used by the American Iron and Steel Institute for similar wrought steels.

X1.2 This nomenclature system has served successfully to accommodate changes in old alloys and to designate new ones.



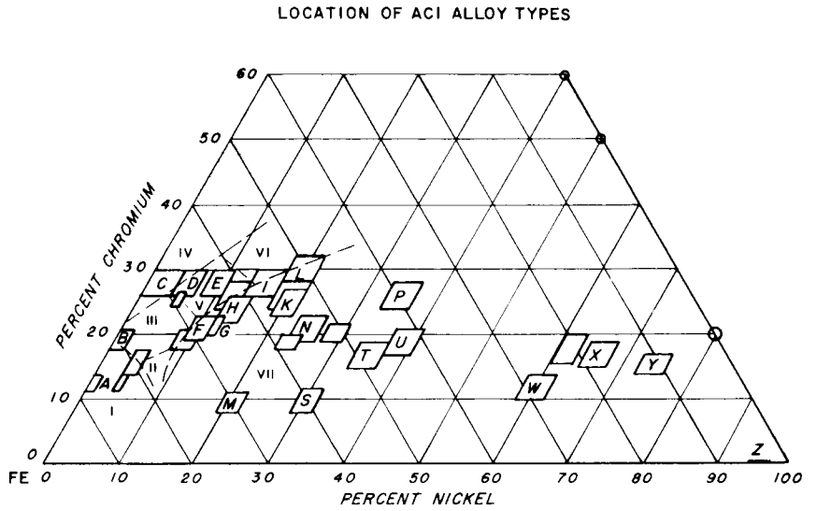
X1.2.1 *Service Classification Letter*—The first letter of the cast stainless steel designation system identifies the intended service application of the alloy. The letter C indicates corrosion-resistant service, and the letter H indicates the heat-resistant service at and above 1200°F (649°C).

X1.2.2 *Ternary Diagram Location Letter*—The second letter indicates the approximate location of the nickel and chromium contents of the alloy grade on the FeCrNi ternary diagram shown in Fig. X1.1.

X1.2.3 *Carbon Content Number*—For C service classifications, this single or dual digit numeral represents the maximum carbon content in units of 0.01%. For H service classifications, this number represents the midpoint of the range of carbon content in terms of 0.01% with a ±0.05% limit.

X1.2.4 *Special Elements Letter*—Additional letters following the numeral represent special chemical elements in the alloy grade, such as M for Molybdenum, C for columbium, Cu for copper, W for tungsten. There are two exceptions: the letter A indicates "Controlled Ferrite," and the letter F indicates "Free Machining."

X1.3 In Fig. X.1.1, unlettered NiCr ranges are associated with the nearest lettered location. They may be the result of differences between corrosion and heat-resistant types or because of the influence of additional elements: for example, the precipitation hardening grade CB-7Cu.



NOTE—The approximate areas of microstructures to be expected at room temperature are indicated as follows:
I—Martensite
II—Martensite and untransformed austenite
III—Ferrite plus martensite and untransformed austenite
IV—Ferrite
V—Ferrite plus austenite
VI—Ferrite plus austenite plus sigma
VII—Austenite
Carbides also may be present depending on carbon content and thermal history.

FIG. X1.1 LETTERS ASSIGNED TO CHROMIUM AND NICKEL RANGES IN ACI DESIGNATION SYSTEM

SPECIFICATION FOR AGE-HARDENING STAINLESS AND HEAT-RESISTING STEEL FORGINGS

SA-705/SA-705M

(Identical with ASTM Specification A 705/A 705M-93)

1. Scope

1.1 This specification covers age-hardening stainless and heat-resisting steel forgings for general use.

1.2 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standards; within the text and tables, the SI units are shown in [brackets]. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 Unless the order specifies an "M" designation, the material shall be furnished to inch-pound units.

NOTE 1—Bar products are covered by Specification A 564/A 564M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 484/A 484M Specification for General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings

A 564/A 564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless and Heat-Resisting Steel Bars and Shapes

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *Other Documents:*

SAE J1086 Recommended Practice for Numbering Metals and Alloys (UNS)

3. Ordering Information

3.1 Orders for forgings under this specification shall include the following information:

3.1.1 Quantity (weight or number of pieces),

3.1.2 Name of material (age-hardening stainless steel forgings),

3.1.3 Dimensions, including prints or sketches,

3.1.4 Type or UNS designation (Table 1),

3.1.5 Heat treated condition (Section 5),

3.1.6 Transverse properties when required (7.4),

3.1.7 ASTM designation and date of issue, and

3.1.8 Special requirements (5.3, 5.4).

3.2 If possible the intended end use of the item should be given on the purchase order, especially when the item is ordered for a specific end use or uses.

NOTE 2—A typical ordering description is as follows: 5 age-hardening stainless steel forgings, Type 630, solution-annealed, ASTM Specification A 705 dated ____. End use: pump blocks for oil well equipment.

4. General Requirements

4.1 In addition to the requirements of this specification, all requirements of the current edition of Specifica-

tion A 484/A 484M shall apply. Failure to comply with the general requirements of Specification A 484/A 484M, constitutes nonconformance with this specification.

5. Manufacture

5.1 Material for forgings shall consist of billets or bars, either forged, rolled or cast, or a section cut from an ingot. The cuts shall be made to the required length by a suitable process. This material may be specified to Specification A 564/A 564M.

5.2 The material shall be forged by hammering, pressing, rolling, extruding, or upsetting to produce a wrought structure throughout and shall be brought as nearly as possible to the finished shape and size by hot working.

5.3 When specified on the order, sample forging may be sectioned and etched to show flow lines and the condition in regard to internal imperfections. When so specified, the question of acceptable and unacceptable metal flow shall be subject to agreement between the manufacturer and the purchaser prior to order entry.

5.4 When specified on the order, the manufacturer shall submit for approval of the purchaser a sketch showing the shape of the rough forging before machining, or before heat treating for mechanical properties.

5.5 The grain size shall be as fine as practicable and precautions shall be taken to minimize grain growth.

5.6 Material of types other than XM-9 shall be furnished in the solution-annealed condition, or in the equalized and over-tempered condition, as noted in Table 2, unless otherwise specified by the purchaser.

5.6.1 Types 630, XM-16, and XM-25 may be furnished in the solution-annealed or age-hardened condition.

6. Chemical Composition

6.1 The steel shall conform to the chemical composition limits specified in Table 1.

6.2 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

7. Mechanical Properties

7.1 The material, as represented by mechanical test specimens, shall conform to the mechanical property requirements specified in Table 2 and shall be capable of developing the properties in Table 3 when heat treated as specified in Table 3.

7.2 The yield strength shall be determined by the offset method as described in the current edition of Test Methods and Definitions A 370. The limiting permanent offset shall be 0.2% of the gage length of the specimen.

7.3 The impact strength shall be determined at 70 to 80°F [20 to 25°C], by Charpy V-notch specimen Type A as described in Test Methods and Definitions A 370.

7.4 Material tensile tested and, when specified, impact tested in the transverse direction (perpendicular to the forging flow lines) and meeting the requirements shown in Table 3 need not be tested in the longitudinal direction.

7.5 Samples cut from forging shall conform to the mechanical properties of Table 3 when heat treated as specified in Tables 2 and 3 and tested in accordance with Test Methods and Definitions A 370.

8. Prolongations for Tests

8.1 Subject to Section 7, the forgings shall be produced with prolongations for testing, unless otherwise specified. The producer may elect to submit an extra forging to represent each test lot instead of prolongations, or the test specimens can be taken from the forgings themselves.

9. Number of Tests

9.1 For all classes of forgings weighing from 5000 to 7000 lb [2300 to 3200 kg] each, at least one tension test shall be made from each forging.

9.2 For all classes of forgings weighing more than 7000 lb [3200 kg] each, one tension test shall be made from each end of each forging. In the case of ring forgings, the tension test specimen shall be removed from each of two locations on the periphery, approximately 180° apart, or insofar as practicable, from opposite ends of the forging.

9.3 For forgings weighing less than 5000 lb [2300 kg] each, one tension test shall be made from each size classification for each heat in each heat treating charge. Where continuous heat treating furnaces are used, tests shall be made on 10% of the forgings of each size classification from each heat subjected to the same heat treatment practice.

10. Keywords

10.1 age-hardening; stainless; steel

TABLE 1
CHEMICAL REQUIREMENTS[A]

Composition, %													
UNS Designation[G]	Type	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Aluminum	Molybdenum	Titanium	Copper	Other Elements
S17400	630	0.07	1.00	0.040	0.030	1.00	15.00–17.50	3.00–5.00	...	...	...	3.00–5.00	[B]
S17700	631	0.09	1.00	0.040	0.030	1.00	16.00–18.00	6.50–7.75	0.75–1.50	...	...	...	...
S15700	632	0.09	1.00	0.040	0.030	1.00	14.00–16.00	6.50–7.75	0.75–1.50	2.00–3.00	...	...	...
S35500	634	0.10–0.15	0.50–1.25	0.040	0.030	0.50	15.00–16.00	4.00–5.00	...	2.50–3.25	...	...	[C]
S17600	635	0.08	1.00	0.040	0.030	1.00	16.00–17.50	6.00–7.50	0.40	...	0.40–1.20	...	...
S15500	XM-12	0.07	1.00	0.040	0.030	1.00	14.00–15.50	3.50–5.50	...	...	...	2.50–4.50	[B]
S13800	XM-13	0.05	0.20	0.010	0.008	0.10	12.25–13.25	7.50–8.50	0.90–1.35	2.00–2.50	...	...	[D]
S45500	XM-16	0.03	0.50	0.015	0.015	0.50	11.00–12.50	7.50–9.50	...	0.50	0.90–1.40	1.50–2.50	[E]
S45503	...	0.010	0.50	0.010	0.010	0.20	11.00–12.50	7.50–9.50	...	0.50	1.00–1.35	1.50–2.50	[E]
S45000	XM-25	0.05	1.00	0.030	0.030	1.00	14.00–16.00	5.00–7.00	...	0.50–1.00	...	1.25–1.75	[F]

[A] Limits are in percent maximum unless shown as a range or stated otherwise.
[B] Columbium plus tantalum 0.15–0.45.
[C] Nitrogen 0.07–0.13.
[D] Nitrogen 0.01.
[E] Columbium plus tantalum 0.10–0.50.
[F] Columbium 8 times carbon minimum.
[G] New designation established in accordance with Practice E 527 and SAEJ1086, Recommended Practice for Numbering Metals and alloys (UNS).

TABLE 2
SOLUTION HEAT TREATMENT

			Mechanical Test Requirements in Solution Treated Condition[A]							
			Tensile Strength, min		Yield Strength, min				Hardenss[B]	
Type	Condition	Solution Treatment	ksi	[MPa]	ksi	[MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, minute %	Rockwell C, max	Brinell, max
630	A	1900 ± 25°F [1040 ± 15°C] (cool as required to below 90°F [32°C])	...	...	...	...	...	...	38	363
631	A	1900 ± 25°F [1040 ± 15°C] (water quench)	...	...	...	...	...	...	Rb89	229
632	A	1900 ± 25°F [1040 ± 15°C] (water quench)	...	...	...	...	...	...	Rb100	269[C]
634[D]	A	1900 ± 25°F [1040 ± 15°C] quench, hold not less than 3 h at minus 100°F or lower	...	...	...	...	...	...	...	363[D]
635	A	1900 ± 25°F [1040 ± 15°C] (air cool)	120	[825]	75	[515]	10	45	32	302
XM-12	A	1900 ± 25°F [1040 ± 15°C] (cool as required to below 90°F [32°C])	...	...	...	...	...	...	38	363
XM-13	A	1700 ± 25°F [925 ± 15°C] (cool as required to below 60°F [16°C])	...	...	...	...	...	...	38	363
XM-16	A	1525 ± 25°F [830 ± 15°C] (cool rapidly)	...	...	...	...	...	...	36	331
S45503	A	1525 ± 25°F [830 ± 15°C] (cool rapidly)	...	...	...	...	...	...	36	331
XM-25	A	1900 ± 25°F [1040 ± 15°C] (cool rapidly)	125[E]	[860]	95	[655]	10	40	33	311

[A] See 6.1.
[B] Either Rockwell C hardness or Brinell is permissible. On sizes of ½ in. (12.70 mm) and smaller. Rockwell C is preferred.
[C] 321 BHN for rounds cold drawn after solution treating.
[D] Equalization and over-tempering treatment 1425 ± 50°F [775 ± 30°C] for not less than 3 h, cool to room temperature, heat to 1075 ± 25°F [580 ± 15°C] for not less than 3 h.
[E] 125 – 165 ksi [860 – 1140 MPa] for sizes up to ½ in. [13 mm].

TABLE 3
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A]

Type	Condition	Suggested Hardening or Aging Treatment, or both[M,N,P] Temperature, °F [°C]	Time, h	Quench	Applicable Thickness, in. and Test Direction[F]	Tensile Strength, min ksi	[MPa]	Yield Strength, min[B] ksi	[MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Hardness[G] Rockwell C, min	Brinell, min	Impact Charpy-V, min ft·lbf	J
630	H900	900 [480]	1.0	air cool	Up to 3 in. incl [75 mm] (L)	190	[1310]	170	[1170]	10	40	40	388	...	...
					Over 3 in. [75 mm] to 8 in. incl [200 mm] (L)						35				
	H925	925 [495]	4.0	air cool	Up to 3 min. incl [75 mm] (L)	170	[1170]	155	[1070]	10	44	38	375	5	6.8
					Over 3 in. [75 mm] to 8 in. incl [200 mm] (L)						38				
	H1025	1025 [550]	4.0	air cool	Up to 8 in. incl [200 mm] (L)	155	[1070]	145	[1000]	12	45	35	331	15	20
	H1075	1075 [580]	4.0	air cool		145	[1000]	125	[860]	13	45	32	311	20	27
	H1100	1100 [595]	4.0	air cool		140	[965]	115	[795]	14	45	31	302	25	34
	H1150	1150 [620]	4.0	air cool		135	[930]	105	[725]	16	50	28	277	30	41
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool				115	[795]	75	[520]	18	55	24	255	55	75
631	RH950	1750°F [955°C] for not less than 10 min, but not more than 1 h, cool rapidly to room temperature. Cool within 24 h to minus 100 ± 10°F [75°C], hold not less than 8 h. Warm in air to room temperature. Heat to 950°F [510°C], hold 1 h, air cool			Up to 4 in. incl. [100 mm] (L)	185	[1280]	150	[1030]	6	10	41	388	...	...
	TH1050	Alternative treatment: 1400°F [760°C] hold 90 min, cool to 55 ± 5°F [15 ± 3°C] within 1 h. Hold not less than 30 min, heat to 1050°F [565°C] hold for 90 min, air cool			Up to 6 in. incl [150 mm] (L)	170	[1170]	140	[965]	6	25	38	352	...	...
632	RH950	Same as Type 631			Up to 4 in. incl [100 mm] (L)	200	[1380]	175	[1210]	7	25	...	415	...	...
	TH1050				Up to 6 in. incl [150 mm] (L)	180	[1240]	160	[1100]	8	25	...	375	...	...

TABLE 3 (CONT'D)
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A]

Type	Condition	Suggested Hardening or Aging Treatment, or both[M,N,P] Temperature, °F [°C]	Time, h	Quench	Applicable Thickness, in. and Test Direction[F]	Tensile Strength, min ksi	[MPa]	Yield Strength, min[B] ksi	[MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Hardness[G] Rockwell C, min	Brinell, min	Impact Charpy-V, min ft·lbf	J
634[C]	H1000	1750 [955] for but not less than 10 min, but not more than 1 h. Water quench. Cool to not higher than minus 100°F [75°C]. Hold for not less than 3 h. Temper at 1000°F [540°C], holding for not less than 3 h.				170	[1170]	155	[1070]	12	25	37	341	...	...
635	H950	950 (510)	0.5	air cool		190	[1310]	170	[1170]	8	25	39	363	...	...
	H1000	100 [540]	0.5	air cool		180	[1240]	160	[1100]	8	30	37	352	...	...
	H1050	1050 [565]	0.5	air cool		170	[1170]	150	[1035]	10	40	35	331	...	...
XM-12	H900	900 [480]	1.0	air cool	Up to 12 in. incl [300 mm][D] (L)	190	[1310]	170	[1170]	10	35	40	388	...	...
					Up to 12 in. incl [300 mm][D] (T)					6	15				
	H925	925 [495]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	170	[1170]	155	[1070]	10	38	38	375	5	6.8
					Up to 12 in. incl [300 mm][D] (T)					7	20			...	...
	H1025	1025 [550]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	155	[1070]	145	[1000]	12	45	35	331	15	20
					Up to 12 in. incl [300 mm][D] (T)					8	27			10	14
	H1075	1075 [580]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	145	[1000]	125	[860]	13	45	32	311	20	27
					Up to 12 in. incl [300 mm][D] (T)					9	28			15	20
	H1100	1100 [595]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	140	[965]	115	[795]	14	45	31	302	25	34
					Up to 12 in. incl [300 mm][D] (T)					10	29			15	20
	H1150	1150 [620]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	135	[930]	105	[725]	16	50	28	277	30	41
					Up to 12 in. incl [300 mm][D] (T)					11	30			20	27
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool			Up to 12 in. incl [300 mm][D] (L)	115	[795]	75	[515]	18	55	24	255	55	75
					Up to 12 in. incl [300 mm][D] (T)					14	35			35	47

TABLE 3 (CONT'D)
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A]

Type	Condition	Suggested Hardening or Aging Treatment, or both[M,N,P] Temperature, °F [°C]	Time, h	Quench	Applicable Thickness, in. and Test Direction[F]	Tensile Strength, min ksi	[MPa]	Yield Strength, min[B] ksi	[MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Hardness[G] Rockwell C, min	Brinell, min	Impact Charpy-V, min ft·lbf	J
XM-13	H950	950 [510]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	220	[1520]	205	[1420]	10	45	45	430	...	...
					Up to 12 in. incl [300 mm][D] (T)						35				
	H1000	1000 [540]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	205	[1420]	190	[1310]	10	50	43	400	...	...
					Up to 12 in. incl [300 mm][D] (T)					10	40				
	H1025	1025 [550]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	185	[1280]	175	[1210]	11	50	41	380	...	...
					Up to 12 in. incl [300 mm] (T)						45				
	H1050	1050 [565]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	175	[1210]	165	[1140]	12	50	40	372	...	...
					Up to 12 in. incl [300 mm] (T)						45				
	H1100	1100 [595]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	150	[1030]	135	[930]	14	50	34	313	...	...
					Up to 12 in. incl [300 mm] (T)						50				
	H1150	1150 [620]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	135	[930]	90	[620]	14	50	30	283	...	...
					Up to 12 in. incl [300 mm] (T)						50				
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool			Up to 12 in. incl [300 mm] (L)	125	[860]	85	[585]	16	55	26	259	...	...
					Up to 12 in. incl [300 mm] (T)						55				
XM-16[H]	H900	900 [480]	4.0	air cool		235	[1620]	220	[1520]	8	30	47	444	...	...
	H950	950 [510]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	220	[1520]	205	[1410]	10	40	44	415	...	...
	H1000	1000 [540]	4.0	air cool		205	[1410]	185	[1280]	10	40	40	363	...	...
S45503[H]	H900	900 [480]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	235	[1620]	220	[1520]	8	30	47	444	...	...
					Up to 6 in. incl [150 mm][K] (T)					4	15				
	H950	950 [510]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	220	[1520]	205	[1410]	10	40	44	415	...	...
					Up to 6 in. incl [150 mm][K] (T)					5	20				
	H1000	1000 [540]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	205	[1410]	185	[1280]	10	40	40	363	...	...
					Up to 6 in. incl [150 mm] (T)					6	25				
XM-25[H]	H900	900 [480]	4.0	air cool	Up to 8 in. incl [200 mm]					10	40				
					Up to 12 in. incl [300 mm][K] (L)	180	[1240]	170	[1170]	10	40	39	363†	...	...
					Up to 12 in. incl [300 mm][K] (T)					6	20				
	H950	950 [510]	4.0	air cool	Up to 8 in. incl [200 mm]					10	40				
					Up to 12 in. incl [300 mm][K] (L)	170	[1170]	160	[1100]	10	40	37	341	...	...
					Up to 12 in. incl [300 mm][K] (T)					7	22				

TABLE 3 (CONT'D)
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A]

Type	Condition	Suggested Hardening or Aging Treatment, or both[M,N,P]			Applicable Thickness, in. and Test Direction[F]	Tensile Strength, min		Yield Strength, min[B]		Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Hardness[G]		Impact Charpy-V, min	
		Temperature, °F [°C]	Time, h	Quench		ksi	[MPa]	ksi	[MPa]			Rockwell C, min	Brinell, min	ft·lbf	J
XM-25[H]	H1000	1000 [540]	4.0	air cool	Up to 8 in. incl [200 mm]					12	45				
					Up to 12 in. incl [300 mm][K] (L)	160	[1100]	150	[1030]	12	45	36	331	...	...
					Up to 12 in. incl [300 mm][K] (T)					6	27				
	H1025	1025 [550]	4.0	air cool	Up to 8 in. incl [200 mm]	150	[1030]	140	[965]	12	45	34	321	...	...
	H1050	1050 [565]	4.0	air cool	Up to 8 in. incl [200 mm]					12	45				
					Up to 12 in. incl [300 mm][K] (L)	145	[1000]	135	[930]	12	45	34	321	...	...
					Up to 12 in. incl [300 mm][K] (T)					9	30				
	H1100	1100 [595]	4.0	air cool	Up to 8 in. incl [200 mm]					16	50				
					Up to 12 in. incl [300 mm][K] (L)	130	[895]	105	[725]	16	50	30	285	...	...
					Up to 12 in. incl [300 mm][K] (T)					11	30				
	H1150	1150 [620]	4.0	air cool	Up to 8 in. incl [200 mm]					15	50				
					Up to 12 in. incl [300 mm][K] (L)	125	[860]	75	[515]	18	55	26	262	...	...
					Up to 12 in. incl [300 mm][K] (T)					12	35				

[A] See 6.1.
[B] See 6.2.
[C] Refer to Table 2 for details on equalize and over temper heat treatment.
[D] Applies to consumable electrode vacuum remelted.
[F] (L) — Longitudinal axis of specimen parallel to direction of grain flow during rolling or forging. (T) — Transverse axis of specimen perpendicular to direction of grain flow during rolling or forging.
[G] Either Rockwell C hardness or Brinell is permissible. On sizes ½ in. (12.70 mm) and smaller, Rockwell C is preferred.
[H] Only tensile strength applicable to sizes up to ½ in. (13 mm).
[K] Consumable electrode remelted only.
[M] Time refers to minimum time material is at temperature and may be extended to obtain required ductility properties.
[N] Unless otherwise noted, temperatures shown are suggested temperatures and may be varied to obtain required tensile properties.
[P] Intermediate temperatures must meet the ductility requirements of the next highest suggested hardening or aging temperature, or both. Example: Type 630 at 1050°F [565°C] must have 13% elongation and 45% reduction, same as for age hardening at 1075°F [580°C].

SPECIFICATION FOR ALLOY STEEL FORGINGS FOR HIGH-STRENGTH PRESSURE COMPONENT APPLICATION

SA-723/SA-723M

(Identical with ASTM Specification A 723/A 723M-94 except for editorial differences in 6.2.2 and 6.2.3.)

1. Scope

1.1 This specification covers requirements for high-strength quenched and tempered alloy steel forgings for pressure vessels, isostatic presses, shock tubes, and similar components.

1.2 These materials are not intended for welded construction.

1.3 Three grades of nickel-chromium-molybdenum steels and six classes of increasing tensile strength are included. The strength class, section size, and configuration of the forging will largely dictate the applicable type(s) of steel.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as the standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 788 Specification for Steel Forgings, General Requirements

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order a detailed drawing, sketch, or written description of the forging and the method of selecting test location (see 6.2). When appropriate, the areas of significant loading in the forging shall be designated.

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Melting Practice* — The steel melting procedures of Specification A 788 shall apply except that the open-

hearth process shall not be used, and that the steel shall be vacuum degassed prior to or during the pouring of the ingot, in order to remove objectionable gases, particularly hydrogen.

4.2 *Discard* — Sufficient discard shall be taken from each ingot to secure freedom from piping and excessive segregation.

4.3 *Heat Treatment:*

4.3.1 Forgings shall be rough-machined prior to final heat treatment if it is necessary to reduce the mass to ensure full hardening or to meet the requirements of 6.2. The risk of cracking during heat treatment with high-hardenability steels of the type covered by this specification should be borne in mind when deciding on the degree of surface preparation before heat treatment.

4.3.2 *Heat Treatment for Mechanical Properties* — Heat treatment shall consist of normalizing (which may be part of the preliminary treatment), reaustenitization, liquid quenching, and tempering. The forgings shall be quenched in a suitable liquid medium by spraying or immersion. Quenching shall be followed by tempering at a minimum temperature of 1000°F [540°C]. The minimum time at tempering temperature shall be ½ h/in. [½ h/25 mm] of maximum section thickness, unless otherwise agreed between supplier and purchaser.

5. Chemical Composition

5.1 *Heat Analysis* — The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1.

5.2 *Product Analysis* — The manufacturer shall use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat. The purchaser may also make this determination in accordance with Specification A 788.

6. Mechanical Properties

6.1 *General Requirements* — The forging shall conform to the requirements of Tables 2 and 3. The largest obtainable tension test specimen as specified in Test Methods and Definitions A 370 (that is, standard round 0.500-in. [12.5-mm] diameter specimen) shall be used. Charpy V-notch Type A impact specimens, as shown in Test Methods and Definitions A 370, shall be used.

6.2 *Sampling* — The mid-point of the gage length of tension test specimens and the area under the notch of impact specimens shall be located in accordance with one of the following methods as specified by the purchaser, or suggested by the supplier and approved by the purchaser. Wherever practical, all testing shall be from integral prolongations of the forging.

6.2.1 *Method 1* — This method shall always be used when the maximum quenched thickness does not exceed 4 in. [100 mm]. Datum points of the specimens, as described in 6.2, shall be located in the forging or test forging (6.2.4) at mid-thickness and at least ⅔ T (T is the maximum heat-treated thickness) from the quenched end surface or nearest adjacent surfaces.

6.2.2 *Method 2* — *t* by 2*t*, where *t* is the distance from the area of significant loading (3.1) to the nearest quenched surface. However, the datum points of the specimens as described in 6.2 shall not be nearer to one quenched surface than ¾ in. [20 mm] and to the second quenched surface than 1½ [40 mm]. When this method of testing is employed, forgings are usually manufactured in accordance with a purchaser-approved drawing showing prequenched dimensions and the location of mechanical test specimens. It is commonly used for disk-type forgings such as tube sheets and covers.

6.2.3 *Method 3* — For maximum quenched thicknesses in excess of 4 in. [100 mm] as heat treated. Where this method of testing is employed, the datum points of the test specimen, as described in 6.2, shall be removed ¼ *T* from the nearest quenched surface and ⅔ *T* from the quenched end surface or nearest adjacent surface.

6.2.4 *Method 4* — Test specimens shall be taken from a representative separate test forging made from the same heat of steel, which shall receive substantially the same reduction and type of hot working, and have a cross section not less than the production forgings which it represents. It shall be heat treated in the same furnace charge and under the same conditions as the production forgings. The test specimen shall be removed using the Method 3 procedure.

6.3 *Thermal Buffers:*

6.3.1 Thermal buffer rings, at least *T* by *T* in cross section or sections of such a ring at least 3 *T* in length, shall be welded to the test end(s) of a forging prior to heat treatment for mechanical properties. The buffer material may be any weldable carbon or low-alloy steel and shall be joined to the forging with a partial penetration-type weld which completely seals the buffered surface. The test coupons shall be removed from the forging in the region buffered by the ring or ring segments. If the latter are used, the test coupons

shall be removed from the forging in the area under the center 1/3 of the buffer ring segment length. In either case, the test specimens shall be located at a minimum distance of 1/2 in. [13 mm] from the buffered surface of the forging and at least 1/4 *T* from a quenched surface of the forging. Buffered weld areas must be at least 1 in. [25 mm] from any finished machining surface of the complete forging.

6.3.2 Bearing in mind the characteristics of the base materials included in this specification, precautions should be taken, such as the use of pre- and post-weld heating and austenitic weld metal, to minimize the occurrence of crack-like defects.

6.3.3 Approval of the purchaser should be obtained for the use of this method.

6.4 Samples shall be removed from the forgings after quenching and tempering.

6.5 *Orientation* — For upset disk forgings, the longitudinal axis of all test specimens shall be oriented in the tangential or radial direction. For all other forgings, the longitudinal axis of the specimens shall be oriented in the direction of maximum working of the forging, or as agreed between manufacturer and purchaser.

6.6 *Number of Tests:*

6.6.1 For forgings weighing 1000 lb [455 kg] or less, as heat treated but not exceeding 80 in. [2030 mm] in length, excluding test material, one tension test and one set of impact tests (three specimens) shall be taken to represent each heat in each heat-treatment charge. This testing shall be repeated at the opposite end of the same test forging, if the heat-treated length excluding test material exceeds 80 in. [2030 mm]. When heat treatment is performed in continuous-type furnaces with suitable temperature control and equipped with recording pyrometers so that complete heat-treatment records are available, a heat-treatment charge shall be considered as any continuous run not exceeding 8 h in duration.

6.6.2 Forgings weighing over 1000 lb [455 kg] but not over 5000 lb [2270 kg] as heat treated and not over 80 in. [2030 mm] in length excluding test material, one tension test and one set of three impact tests shall be removed from each forging. When the length of the forging exceeds 80 in. [2030 mm] this testing shall be repeated at the opposite end of the forging.

6.6.3 Forgings exceeding 5000 lb [2270 kg] and not over 80 in. [2030 mm] in length, excluding test material, shall have one tension test and one set of three impact tests removed from each of two locations, 180° apart. For forgings with lengths exceeding 80 in. [2030 mm] this testing shall be repeated at the opposite end of the forging.

7. Nondestructive Examination Requirements

7.1 *Ultrasonic Examination:*

7.1.1 Forgings shall be ultrasonically examined in accordance with the procedures of Practice A 388/A 388M.

7.1.1.1 *Straight-Beam Examination:*

(a) Unless otherwise specified, the back-reflection method of tuning shall be used in accordance with Practice A 388/A 388M.

(b) In addition to the reportable conditions of Practice A 388, indications exceeding the resultant back-reflection shall be recorded.

(c) A forging shall be unacceptable when one or more reflections are present producing indications accompanied by a complete loss of back-reflection, not attributable to nor associated with the geometric configuration. For this purpose, a back-reflection of less than 5% of full screen height shall be considered complete loss of back-reflection.

7.1.1.2 *Angle-Beam Examination:*

(a) Calibration notches shall be cut into the inside diameter and outside diameter surfaces in accordance with Practice A 388.

(b) A forging that contains a discontinuity which results in an indication exceeding the amplitude of the reference line is subject to rejection.

(c) The report of the ultrasonic test shall be in compliance with Practice A 388/A 388M.

(d) Additional nondestructive examination or trepanning may be employed to resolve questions of interpretation of ultrasonic indications. The manufacturer shall accept responsibility for injurious defects that will not be removed in final machining.

7.2 *Magnetic Particle Examination:*

7.2.1 Each forging shall be examined by magnetic particle methods described in Test Method A 275/A 275M. Acceptance and rejection standards shall be as follows: Only indications with major dimensions greater than 1/16 in. [1.6 mm] shall be considered relevant. The following relevant indications are unacceptable:

7.2.1.1 Any linear indications greater than 1/16 in. [1.6 mm] long for materials less than 5/8 in. [16

mm] thick; greater than $\frac{1}{8}$ [3.2 mm] long for materials from $\frac{5}{8}$ in. to under 2 in. [50 mm] thick; and $\frac{3}{16}$ in. [4.8 mm] long for materials 2 in. [50 mm] thick and greater. A linear indication is defined as one whose length is three times its width.

7.2.1.2 Rounded indications with dimensions greater than $\frac{1}{8}$ in. [3.2 mm] for thicknesses less than $\frac{5}{8}$ in. [16 mm], and greater than $\frac{3}{16}$ in. [4.8 mm] for thicknesses $\frac{5}{8}$ in. [16 mm] and greater.

7.2.1.3 Four or more relevant indications in a line separated by $\frac{1}{16}$ in. [1.6 mm] or less, edge to edge.

7.2.1.4 Ten or more relevant indications in any 6 in.^{2} [3870 mm^2] of surface with the major dimension of this area not to exceed 6 in. [150 mm] when it is taken in the most unfavorable orientation relative to the indications being evaluated.

8. Rework and Retreatment

8.1 Repair welding shall not be permitted. For retreatment, see 7.2.1.

9. Certification and Reports

9.1 In addition to the certification requirements of Specification A 788, the manufacturer shall include the following in the certification data:

9.1.1 Results of the product analysis,

9.1.2 Method used to locate mechanical test specimens (see Section 6), and

9.1.3 Sketches or drawings as necessary to supplement the nondestructive examination report.

10. Packaging and Package Marking

10.1 Marking shall be in accordance with Specification A 788 but stamping shall be permitted only in areas designated by the purchaser. If no such suitable area is available, a separate nameplate, with the required stamping, shall be permanently affixed to the vessel in a manner that will not be injurious to the vessel.

11. Keywords

11.1 alloy steel forgings; high pressure vessels; high strength; impact tested; isostatic presses; nonweldable; quenched and tempered; vacuum-treated steel

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %		
	Grade 1	Grade 2	Grade 3
Carbon, max	0.35	0.40	0.40
Manganese, max	0.90	0.90	0.90
Phosphorus, max	0.015	0.015	0.015
Sulfur, max	0.015	0.015	0.015
Silicon, max	0.35	0.35	0.35
Nickel	1.5 to 2.25	2.3 to 3.3	3.3 to 4.5
Chromium	0.80 to 2.00	0.80 to 2.00	0.80 to 2.00
Molybdenum	0.20 to 0.40	0.30 to 0.50	0.40 to 0.80
Vanadium, max	0.20	0.20	0.20

TABLE 2
TENSILE REQUIREMENTS

	Class 1	Class 2	Class 2a	Class 3[A]	Class 4[B]	Class 5[C]
Tensile strength, min, ksi [MPa]	115 [795]	135 [930]	145 [1000]	155 [1070]	175 [1205]	190 [1310]
Yield strength, 0.2% offset, min, psi [MPa]	100 [690]	120 [825]	130 [895]	140 [965]	160 [1105]	180 [1240]
Elongation in 2 in. or 50 mm, min, %	16	14	12.5	13	12	10
Reduction of area, min, %	50	45	43	40	35	30

[A] Typical maximum section size of 10 in. [255 mm] for open-ended vessels, or 7 in. [180 mm] for blind-ended vessels.
[B] Typical maximum section size of 6 in. [150 mm] for open-ended vessels, or 4 in. [100 mm] for blind-ended vessels.
[C] Typical maximum section size of 4 in. [100 mm].

TABLE 3
CHARPY V-NOTCH IMPACT REQUIREMENTS AT 40°F [4.5°C] MAX[A]

	Class 1	Class 2	Class 2a[A]	Class 3[B]	Class 4[C]	Class 5[D]
Minimum average value of set of three specimens, ft · lbf[E] (J)	35 [47]	30 [41]	28 [38]	25 [34]	20 [27]	12 [16]
Minimum value of one specimen, ft·lbf (J)	30 [41]	25 [34]	23 [31]	20 [27]	15 [20]	10 [14]

[A] Or such other lower temperature as is specified when supplementary requirement S2 is involved.
[B] Typical maximum section size of 10 in. [255 mm] for open-ended vessels, or 7 in. [180 mm] for blind-ended vessels.
[C] Typical maximum section size of 6 in. [150 mm] for open-ended vessels, or 4 in. [100 mm] for blind-ended vessels.
[D] Typical maximum section size of 4 in. [100 mm].
[E] Not more than one specimen from a set may be below this value.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Charpy V-Notch Impact Transition Curve

S1.1 Sufficient impact tests shall be made from the forging test material to establish a temperature-absorbed energy curve. The test temperature range shall be wide enough to establish the upper and lower shelf foot · pound-force energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

S1.2 Instead of plotting an impact transition curve, impact requirements may be specified as 50% fibrous fracture at a specified maximum temperature.

S2. Additional Charpy Data

S2.1 The percent shear fracture and mils of lateral expansion, defined in Test Methods and Definitions A 370, shall be reported for each Charpy specimen tested.

S3. Charpy Impact Tests

S3.1 Charpy impact tests shall be made in accordance with the provisions of Section 6 of this specification, except that the tests shall be at a specified temperature lower than 40°F [4.5°C]. These tests shall be instead of those specified in Section 6, and shall meet the requirements of Table 3.

S4. Impact Testing

S4.1 For Class 2a forgings, impact tests shall be made in accordance with the provisions of Section 6 of this specification except that the acceptance criteria shall be a minimum of 45 ft·lbf [61 J] and 25 mils [0.635 mm] lateral expansion at a test temperature specified by the purchaser.

S5. Mechanical Test Location Discard

S5.1 Instead of the discard of $\frac{1}{4}\ T \times \frac{2}{3}\ T$ required by 6.2.3, a minimum discard of $\frac{1}{4}\ T \times T$ shall be employed for Method 3.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, QUENCHED AND TEMPERED, FOR WELDED LAYERED PRESSURE VESSELS

SA-724/SA-724M

(Identical with ASTM Specification A 724/A 724M-90.)

1. Scope

1.1 This specification covers steel plates in three grades of carbon steel, designated Grades A, B, and C. At the option of the supplier, Grade C may be produced with a boron addition up to the maximum content specified in Section 6. The plates are quenched-and-tempered and are primarily intended for welded-layered pressure vessels.

1.2 Material under this specification is available in three grades as follows:

Grade	Yield Strength, min, ksi [MPa]	Tensile Strength, ksi [MPa]
A	70 [485]	90–110 [620–760]
B	75 [515]	95–115 [655–795]
C	70 [485]	90–110 [620–760]

1.3 The maximum thickness of plates supplied under this specification is limited only by the capability of the chemical composition to meet the specified mechanical requirements. However, current practice normally limits the maximum thickness to 78 in. [22 mm] for Grades A and B, and to 2 in. [50 mm] for Grade C.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Document

2.1 *ASTM Standard:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and weight, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Process* — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be quenched from a temperature in the range from 1600 to 1700°F [870 to 925°C]. Grades A and B shall then be tempered at not less than 1100°F [595°C], and Grade C shall then be tempered at not less than 1150°F [620°C]. The tempering soaking time shall be not less than 12 h.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Mechanical Properties

7.1 *Tension Test Requirements:*

7.1.1 The material as represented by the tension test specimens shall conform to the requirements shown in Table 2.

7.1.2 The test specimen shall be the $1\frac{1}{2}$ in. [40 mm] rectangular specimen. The elongation shall be measured in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max:			
Heat analysis	0.18	0.20	0.22
Product analysis	0.22	0.24	0.26
Manganese:			
Heat analysis	1.00–1.60	1.00–1.60	1.10–1.60
Product analysis	0.92–1.72	0.92–1.72	1.02–1.72
Phosphorus, max[A]	0.035	0.035	0.035
Sulfur, max[A]	0.035	0.035	0.035
Silicon, max:			
Heat analysis	0.55	0.50	0.20–0.60
Product analysis	0.60	0.55	0.18–0.65
Copper, max:[B]			
Heat analysis	0.35	0.35	0.35
Product analysis	0.38	0.38	0.38
Nickel, max:[B]			
Heat analysis	0.25	0.25	0.25
Product analysis	0.28	0.28	0.28
Chromium, max:[B]			
Heat analysis	0.25	0.25	0.25
Product analysis	0.29	0.29	0.29
Molybdenum, max:[B]			
Heat analysis	0.08	0.08	0.08
Product analysis	0.09	0.09	0.09
Vanadium, max:[B]			
Heat analysis	0.08	0.08	0.08
Product analysis	0.09	0.09	0.09
Boron, max	. . .	. . .	0.005[C]

[A] Applies to both heat and product analyses.
[B] When analysis shows that the amount of an element is 0.02% or lower, the value may be reported as ≦0.02%.
[C] If boron is less than 0.001%, the analysis report for the element may be stated as "<0.001."

TABLE 2
TENSILE REQUIREMENTS

	Grades A and C ksi [MPa]	Grade B ksi [MPa]
Tensile strength	90–110 [620–760]	95–115 [655–795]
Yield strength, min	70 [485]	75 [515]
Elongation in 2 in. [50 mm], min, %[A,B]	19	17

[A] See Specification A 20/A 20M.
[B] See 7.1.2.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Several of those that are considered suitable for use with this specification are listed by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Production Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4. Charpy V-Notch Impact Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination,

S9. Magnetic Particle Examination, and

S14. Bend Test.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, MOLYBDENUM

SA-204/SA-204M

(Identical to ASTM Specification A 204/A 204M-93)

1. Scope

1.1 This specification covers molybdenum-alloy steel plates, intended particularly for welded boilers and other pressure vessels.

1.2 Material under this specification is available in three grades having different strength levels as follows:

Grade	Tensile Strength, ksi [MPa]
A	65-85 [450-585]
B	70-90 [485-620]
C	75-95 [515-655]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

Grade	Maximum Thickness, in. [mm]
A	6 [150]
B	6 [150]
C	4 [100]

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, hr etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed.

5. Heat Treatment

5.1 Plates $1\frac{1}{2}$ in. [40 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved or both.

5.2 Plates over $1\frac{1}{2}$ in. [40 mm] in thickness shall be normalized.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements* — The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max[A];			
Up to 1 in. [25 mm] incl, in thickness	0.18	0.20	0.23
Over 1 in. to 2 in. [50 mm] incl, in thickness	0.21	0.23	0.26
Over 2 in. to 4 in. [100 mm] incl, in thickness	0.23	0.25	0.28
Over 4 in. [100 mm] in thickness	0.25	0.27	0.28
Manganese, max:			
Heat analysis	0.90	0.90	0.90
Product analysis	0.98	0.98	0.98
Phosphorus, max[A]	0.035	0.035	0.035
Sulfur, max[A]	0.035	0.035	0.035
Silicon:			
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45
Molybdenum:			
Heat analysis	0.45–0.60	0.45–0.60	0.45–0.60
Product analysis	0.41–0.64	0.41–0.64	0.41–0.64

[A] Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

	Grade A		Grade B		Grade C	
	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]
Tensile strength	65–85	[450–585]	70–90	[485–620]	75–95	[515–655]
Yield strength, min[A]	37	[255]	40	[275]	43	[295]
Elongation in 8 in. [200 mm], min, %	19[B]		17[B]		16[B]	
Elongation in 2 in. [50 mm], min, %	23[B]		21[B]		20[B]	

[A] Determined by either the 0.2% offset method or the 0.5% extension-under-load method.
[B] See Specification A20/A 20M.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed in this section by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR SEAMLESS CARBON-MOLYBDENUM ALLOY-STEEL BOILER AND SUPERHEATER TUBES

SA-209/SA-209M

Identical with ASTM Specification A 209/A 209M-95) 98

1. Scope

1.1 This specification covers several grades of minimum-wall-thickness, seamless, carbon-molybdenum alloy-steel, boiler and superheater tubes.

1.2 This specification covers tubes ½ to 5 in. [12.7 to 127 mm] inclusive, in outside diameter and 0.035 to 0.500 in. [0.9 to 12.7 mm], inclusive, in minimum wall thickness.

1.3 An optional supplementary requirement is provided and, when desired, shall be so stated in the order.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Document

2.1 *ASTM Standard:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

3. Ordering Information 98

3.1 Orders for material under this specification shall include the following as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Names of material (seamless tubes),

3.1.3 Grade (Table 1),

3.1.4 Manufacture (hot-finish or cold-finished),

3.1.5 Size (outside diameter and minimum wall thickness),

3.1.6 Length (Specific or random),

3.1.7 Test reported required (see Certification Section of Specification A 450/A450M),

3.1.8 Specification designation, and

3.1.9 Special requirements and any supplementary requirements selected.

4. General Requirements 98

4.1 Material furnished under this specification should conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

5. Manufacture

5.1 *Steelmaking Practice* — The steel shall be killed.

98 **5.2** The tubes shall be made by the seamless process and shall be either hot finished or cold-finished, as specified.

6. Heat Treatment

98 **6.1** Hot-finished tubes shall be heat treated at a temperature of 1200°F [650°C] or higher. Cold-finished tubes shall, after the final cold finishing, be heat treated at a temperature of 1200°F [650°C] or higher, or tubing may be furnished in the full-annealed, isothermal annealed, or normalized and tempered condition. If furnished in the normalized and tempered condition, the minimum tempering temperature shall be 1200°F [650°C].

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Product Analysis

8.1 An analysis shall be made by the manufacturer of one billet or one tube from each heat. The chemical composition thus determined, shall conform to the requirement specified.

8.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 1) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 1 — For flattening and flaring requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

NOTE 2 — For tension and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

9. Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

9.2 Table 4 gives the computed minimum elongation values for each $\frac{1}{32}$ in. [8.0 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation: 98

$$E = 48t + 15.00 \; [E = 1.87t + 15.00] \qquad (1)$$

where:

E = elongation in 2 in. [50 mm], %, and,
t = actual thickness of specimen, in. [mm].

10. Hardness Requirements

10.1 The tubes shall have a hardness not exceeding the values in Table 5. 98

11. Mechanical Tests Required

11.1 *Tension Test* — One Tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 2).

11.2 *Flattening Test* — One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring test, from each lot (Note 1).

11.3 *Flaring Test* — One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

11.4 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 2).

11.5 *Hydrostatic Test* — Each tube shall be subjected to the hydrostatic test, or, instead of this test a nondestructive electric test may be used when specified by the purchaser.

12. Forming Operations

12.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding and bending operations necessary for application without developing defects.

13. Product Marking

98 **13.1** In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include whether the tube is hot-finished or cold-finished.

98 14. Keywords

14.1 boiler tubes; carbon; seamless steel tube; steel tube; superheater tubes

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade T1	Grade T1a	Grade T1b
Carbon	0.10–0.20	0.15–0.25	0.14 max
Manganese	0.30–0.80	0.30–0.80	0.30–0.80
Phosphorus, max	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025
Silicon	0.10–0.50	0.10–0.50	0.10–0.50
Molybdenum	0.44–0.65	0.44–0.65	0.44–0.65

98

TABLE 2
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
2 in. [50.8 mm] and over in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

98

TABLE 3
TENSILE REQUIREMENTS

	Grade T1	Grade T1b	Grade T1a
Tensile strength, min, ksi [MPa]	55 [380]	53 [365]	60 [415]
Yield strength, min, ksi [MPa]	30 [205]	28 [195]	32 [220]
Elongation in 2 in. or 50 mm, min, %	30	30	30
For longitudinal strip tests a deduction shall be made for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage	1.50[A]	1.50[A]	1.50[A]
When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimen with the gage length equal to 4*D* (four times the diameter) is used	22	22	22

[A] Table 4 gives the computed minimum values.

TABLE 4
COMPUTED MINIMUM VALUES

98

Wall Thickness		Elongation in 2 in. or mm, min, %[A]
in.	mm	
5/16 (0.312)	8	30
9/32 (0.281)	7.2	29
1/4 (0.250)	6.4	27
7/32 (0.219)	5.6	26
3/16 (0.188)	4.8	24
5/32 (0.156)	4	22
1/8 (0.125)	3.2	21
3/32 (0.094)	2.4	20
1/16 (0.062)	1.6	18

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

TABLE 5
HARDNESS REQUIREMENTS

98

	Brinell Hardness Number (Tubes 0.200 in. [5.1 mm] and over in Wall Thickness)	Rockwell Hardness Number (Tubes less than 0.200 in. [5.1 mm] in Wall Thickness)
Grade T1	146	B80
Grade T1a	153	B81
Grade T1b	137	B77

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Surface Condition

S1.1 If pickling or shot blasting, or both, are required, this shall be specifically stated in the order. Details of this supplemental requirement shall be agreed upon between the manufacturer and the purchaser.

SPECIFICATION FOR SEAMLESS MEDIUM-CARBON STEEL BOILER AND SUPERHEATER TUBES

SA-210/SA-210M

(Identical with ASTM Specification A 210/A 210M-95 except for editorial differences in Table 2) 98

1. Scope

1.1 This specification covers minimum-wall-thickness, seamless medium-carbon steel, boiler tubes and boiler flues, including safe ends (Note 1), arch and stay tubes, and superheater tubes.

NOTE 1 — This type is not suitable for safe ending by forge welding.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ½ in. to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.500 in. [0.9 to 12.7 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520, shall supplement and supersede the requirements of this specification.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction

3. Ordering Information 98

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (seamless tubes),

3.1.3 Grade,

3.1.4 Manufacture (hot-finished or cold-finished),

3.1.5 Size (outside diameter and minimum wall thickness),

3.1.6 Length (specific or random),

3.1.7 Optional requirements (Sections 7 and 10),

3.1.8 Test report required (see Certification Specification of Specification A 450/A 450M),

3.1.9 Specification designation, and

3.1.10 Special requirements

98 **4. General Requirements**

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

5. Manufacture

5.1 *Steelmaking Practice* — The steel shall be killed.

98 **5.2** The tubes shall be made by the seamless process and shall be either hot-finished or cold-finished, as specified.

6. Heat Treatment

98 **6.1** Hot-finished tubes need not be heat treated. Cold-finished tubes shall be given a subcritical anneal, a full anneal, or a normalizing heat treatment after the final cold-finishing process.

7. Surface Condition

7.1 If pickling or shot blasting or both are required, this shall be specifically stated in the order.

8. Chemical Composition

8.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8.2 When a grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted.

9. Product Analysis

9.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube or billet per heat. The chemical composition thus determined shall conform to the requirements specified.

9.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise, all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 2 — For flattening and flaring requirements, the term "lot" applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

NOTE 3 — For tensile and hardness test requirements, the term "lot" applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

10. Tensile Requiremnts

10.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

10.2 Table 4 gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation: 98

$$E = 48t + 15.00 \; [E = 1.87t + 15.00]$$

where:

E = elongation in 2 in. or 50 mm, %, and
t = actual thickness of specimen, in. [mm].

11. Hardness Requirements

11.1 The tubes shall have a hardness not exceeding the following: 79 HRB or 143 HRB for Grade A-1, 89 HRB or 179 HRB for Grade C.

12. Mechanical Tests Required

12.1 *Tension Test* — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 3).

12.2 *Flattening Test* — One flattening test shall be made on specimens from each end of one finished tube from each lot (Note 2), but not the one used for the flaring test. Tears or breaks occurring at the 12 or 6

o'clock positions on Grade C tubing with sizes of 2.375 in. [60.3 mm] in outside diameter and smaller shall not be considered a basis for rejection.

12.3 *Flaring Test* — One flaring test shall be made on specimens from each end of the one finished tube from each lot (Note 2,) but not the one used for the flattening test.

12.4 *Hardness Test* — Brinell or Rockwell hardness test shall be made on specimens from two tubes from each lot (Note 3).

12.5 *Hydrostatic or Nondestructive Electric Test* — Each tube shall be subjected to the hydrostatic, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

13. Forming Operations

13.1 When inserted in the boiler, tubes shall stand expanding and beading without showing cracks or flaws. When properly manipulated, superheater tubes shall stand all forging, welding and bending operations necessary for application without developing defects.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall indicate whether the tube is hot-finished or cold-finished. **98**

15. Keywords

15.1 boiler tubes; carbon; seamless steel tube; steel tube; superheater tubes **98**

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %	
	Grade A-1	Grade C
Carbon[A], max	0.27	0.35
Manganese	0.93 max	0.29–1.06
Phosphorus, max	0.035	0.035
Sulfur, max	0.035	0.035
Silicon, min	0.10	0.10

[A] For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted up to a maximum of 1.35%.

98

TABLE 2
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. (50.8 mm) and over in diameter and 0.200 in. (5.1 mm) and over in wall thickness	not more than 50 tubes
2 in. (50.8 mm) and over in outside diameter and under 0.200 in. (5.1 mm) in wall thickness	not more than 75 tubes
Less than 2 in. (50.8 mm) but over 1 in. (25.4 mm) in outside diameter or over 1 in. in outside diameter and under 0.200 in. (5.08 mm) in wall thickness	not more than 75 tubes
1 in. (25.4 mm) or less in outside diameter	not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

98

	Grade A-1	Grade C
Tensile strength, min, ksi [MPa]	60 [415]	70 [485]
Yield strength, min, ksi [MPa]	37 [255]	40 [275]
Elongation in 2 in. or 50 mm, min, %	30	30
For longitudinal strip tests, a deduction shall be made for each $^{1}/_{32}$ in. [0.8 mm] decrease in wall thickness under $^{5}/_{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points	1.50[A]	1.50[A]
When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimen with the gage length equal to 4*D* (four times the diameter) is used	22	20

[A] See Table 4 for the computed minimum values.

TABLE 4
COMPUTED MINIMUM ELONGATION VALUES[A]

98

Wall Thickness, in. [mm]	Elongation in 2 in. or 50 mm, min, %
$^{5}/_{16}$ (0.312) [8]	30
$^{9}/_{32}$ (0.281) [7.2]	28
$^{1}/_{4}$ (0.250) [6.4]	27
$^{7}/_{32}$ (0.219) [5.6]	26
$^{3}/_{16}$ (0.188) [4.8]	24
$^{5}/_{32}$ (0.156) [4]	22
$^{1}/_{8}$ (0.125) [3.2]	21
$^{3}/_{32}$ (0.094) [2.4]	20
$^{1}/_{16}$ (0.062) [1.6]	18
0.062 to 0.035 [1.6 to 0.9], excl	17
0.035 to 0.022 [0.9 to 0.6], excl	16
0.022 to 0.015 [0.6 to 0.4], incl	16

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

SPECIFICATION FOR SEAMLESS FERRITIC AND AUSTENITIC ALLOY-STEEL BOILER, SUPERHEATER, AND HEAT-EXCHANGER TUBES

SA-213/SA-213M

(Identical with ASTM Specification A 213/A 213M-95a except for editorial differences in 6.1, 6.1.1 and the deletion of S3, and clarified heat treatment requirements in 6.4.)

1. Scope

1.1 This specification covers minimum-wall-thickness, seamless ferritic and austenitic steel, boiler and superheater tubes and austenitic steel heat-exchanger tubes, designated Grades T5, TP304, etc. These steels are listed in Tables 1 and 2, respectively.

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP310HCbN, TP316H, TP321H, TP347H, TP347HFG (fine grained) and TP348H are modifications of Grades TP304, TP309S, TP309Cb, TP310S, TP310Cb, TP316, TP321, TP347, and TP348, and are intended for high-temperature service, such as for superheaters and reheaters.

1.3 The tubing sizes and thicknesses usually furnished to this specification are $\frac{1}{8}$ in. [3.2 mm] in inside diameter to 5 in. [127 mm] in outside diameter and 0.015 to 0.500 in. [0.4 to 12.7 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.4 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.5 Optional supplementary requirements are provided and, when desired, shall be so stated in the order.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

E 112 Test Methods for Determining Average Grain Size

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (seamless tubes),

4.1.3 Grade (Tables 1 and 2),

4.1.4 Manufacture (hot finished or cold finished),

4.1.5 Controlled structural characteristics (see 6.2),

4.1.6 Size (outside diameter and minimum wall thickness),

4.1.7 Length (specific or random),

4.1.8 Test report required (see Certification Section of Specification A 450/A 450M),

4.1.9 Specification designation, and

4.1.10 Special requirements and any supplementary requirements selected.

5. Materials and Manufacture

5.1 Tubes shall be made by the seamless process and shall be either hot finished or cold finished, as specified. Grade TP347HFG shall be cold finished.

5.2 *Grain Size:*

5.2.1 The grain size of Grades 304H, 316H, 321, 347H, 348H, and 310HCbN, as determined in accordance with Test Methods E 112, shall be No. 7 or finer.

5.2.2 The grain size of cold-worked Grade TP321H, as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

5.2.3 The grain size of TP309H, TP309HCb, TP310H and TP310HCb, as determined in accordance with Test Methods E 112, shall be No. 6 or coarser.

5.2.4 The grain size or cold-worked Grade TP347HFG as determined in accordance with Test Methods E 112 shall be between No. 7 and No. 10.

6. Heat Treatment

6.1 All tubes of grades shown in Table 1, except T5c and T91, and in accordance with 6.1.1 shall be reheated and furnished in the full-annealed, isothermal annealed, or normalized and tempered condition. If furnished in the normalized and tempered condition, the minimum tempering temperature for Grades T5, T5b, T9, T21, and T22 shall be 1250°F [675°C], and the minimum tempering temperature for Grades T11, and T17, shall be 1200°F [650°C].

6.1.1 Tubing of Grades T2 and T12 either hot-finished or cold-drawn, may be given a final heat treatment at 1200 to 1350°F [650 to 730°C] instead of heat treatments specified in 6.1 at the option of the manufacturer.

6.1.2 All tubing of Grade T5c shall be given a final heat treatment of approximately 1350°F [730°C] for a proper time, followed by air or furnace cooling.

6.1.3 Grade T91 shall be normalized at 1900°F [1040°C] minimum and tempered at 1350°F [730°C] minimum as a final heat treatment.

6.1.4 Grade T92 shall be normalized at 1900°F [1040°C] minimum and tempered at 1350°F [730°C] minimum as a final heat treatment.

NOTE 1 — Isothermal annealing as applied to tubular products, may involve austenitizing a ferrous alloy and then cooling to and holding within the range of temperature at which austenite transforms to a relatively soft ferrite-carbide aggregate.

6.2 If any controlled structural characteristics are required these shall be so specified as to be a guide as to the most suitable heat treatment.

6.3 All austenitic tubes shall be furnished in the heat-treated condition. The heat-treatment procedure, except for the H grades and S30815, shall consist of heating the material to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means.

6.4 All H, S30815, S33228 and S31272 grades shall be furnished in the solution-treated condition. For these grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. If cold working is involved in processing, the minimum solution treating temperature for Grades TP321H, TP347H and TP348H shall be 2000°F [1100°C] and for Grades TP304H, and TP316H, 1900°F [1040°C]. If the H grade is hot-rolled, the minimum solution treatment for Grades TP321H, TP347H, and TP348H shall be 1925°F [1050°C], and for Grades TP304H, and TP316H, 1900°F [1040°C]. The minimum solution treating temperature for S30815 and S31272 shall be 1920°F [1050°C]. The minimum solution treating temperature for S33228 shall be 2050°F [1120°C]. The minimum solution treating temperature for TP309H, TP309HCb, TP310H, and TP310HCb shall be 1900°F [1037°C]. The minimum solution treating temperature for TP310HCbN shall be 2000°F

[1110°C] and sufficient to produce a grain size of No. 7 or coarser.

6.5 The heat treatment of cold-worked TP347HFG comprises a softening heat treatment prior to cold-working, and a solution heat treatment after final cold-working. The softening temperature shall be at least 90°F [50°C] higher than the solution heat treatment temperature which shall be at 2150°F [1180°C] minimum.

6.6 Tubing of Grade 18Cr-2M shall be given a final heat treatment of 1400°F [760°C] or higher, and cooled in such a manner as to meet the requirements of this specification.

6.7 The minimum solution treating temperature for grade UNS S21500 shall be 1920°F [1050°C]. A maximum solution treating temperature of 2100°F [1150°C] is recommended.

6.8 A solution annealing temperature above 1950°F [1065°C] may impair resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP309HCb, TP310HCb, TP310HCbN, TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high-temperature solution anneal (see Supplementary Requirement S2).

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Tables 1 and 2.

8. Product Analysis

8.1 An analysis of either one billet or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

8.2 For Grade T91 the carbon content may vary for the product analysis by −0.01% and +0.02% from the specified range as per Table 1.

8.3 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 2 — For flattening and flaring requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 3.

NOTE 3 — For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

9. Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties prescribed in Table 4.

10. Hardness Requirements

10.1 *Ferritic Grades:*

10.1.1 Grades T5b, T7, and T9 shall have a hardness not exceeding 179 HB/190 HV (89 HRB). Grade T91 and T92 shall have a hardness not exceeding 250 HB/265 HV (25 HRC).

10.1.2 Grade 18Cr-2Mo shall have a hardness not exceeding 217 HB/230 HV (96 HRB).

10.1.3 All other ferritic grades shall have a hardness not exceeding 163 HB/170 HV (85 HRB).

10.2 *Austenitic Grades:*

10.2.1 Grades TP201 and TP202 shall have a hardness not exceeding 219 HB/230 HV (95 HRB).

10.2.2 Tubes fabricated from S30815, S31272, S31050, and S25700 shall have a hardness not exceeding 217 HB (95 HRB).

10.2.3 Tubes fabricated from TP310HCbN shall have a hardness not exceeding 256 HB (100 HRB).

10.2.4 XM-19 (UNS S20910) shall have a hardness not exceeding 250 HB/265 HV (25 HRC).

10.2.5 All other austenitic grades shall have a hardness not exceeding 192 HB/200 HV (90 HRB).

11. Mechanical Tests and Grain Size Determinations Required

11.1 *Tension Test* — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 3).

11.2 *Flattening Test* — One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring test, from each lot (Note 2).

11.3 *Flaring Test* — One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 2).

11.4 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 3).

11.5 *Hydrostatic Test* — Each tube shall be subjected to the hydrostatic test, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

11.6 *Grain Size* — Grain size determinations on Grade TP309H, TP309HCb, TP310H, TP310HCb, TP310HCbN, TP321H, TP347HFG, and UNS S32615 shall be made on the same number of tubes as prescribed for the flattening test.

12. Forming Operations

12.1 Tubes when inserted in the boiler or tube sheet shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

NOTE 4 — Certain of the ferritic steels covered by this specification will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures, particularly the 4 to 9% chromium steels. Therefore, operations that involve heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

13. Surface Condition

13.1 The ferritic cold drawn steel tubes shall be free of scale and suitable for inspection. A slight amount of oxidation is not considered scale.

13.2 Ferritic hot rolled steel tubes shall be free of loose scale and suitable for inspection.

13.3 Austenitic steel tubes shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

13.4 Any special finish requirement shall be subject to agreement between the supplier and the purchaser.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include whether the tube is hot finished or cold drawn. For Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, TP347HFG, TP348H, S21500, S33228, and S30815, the marking shall also include the heat number and heat-treatment lot identification. When either T2 or T12 are ordered with sulfur content higher than 0.025 but equal or less than 0.045, the marking shall include the grade with the designation, S; example T2S and T12S.

15. Keywords

15.1 alloy steel tube; austenitic stainless steel; boiler tubes; ferritic stainless steel; heat exchanger tube; high-temperature applications; seamless steel tube; steel tube; superheater tubes; temperature service applications-high

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Stress-Relieved Annealed Tubes

S1.1 For use in certain corrosives, particularly chlorides where stress corrosion may occur, tubes in Grades TP304L, TP316L, TP321, TP347, and TP348 may be specified in the stress-relieved annealed condition.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1500 to 1650°F [815 to 900°C] after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

S1.3 Straightness of the tubes shall be a matter of negotiation between the purchaser and supplier.

S2. Stabilizing Heat Treatment

S2.1 Subsequent to the solution anneal required in Section 6, Grades TP309HCb, TP310HCb, TP310HCbN, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S3. DELETED

S4. Intergranular Corrosion Test

S4.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE 5 — Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S4.2 A stabilization heat treatment in accordance with Supplementary Requirement S2 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

TABLE 1
CHEMICAL REQUIREMENTS FOR FERRITIC STEEL

	Composition, %									
Grade	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Titanium	Vanadium, min	Other Elements
T2 [Note (3)]	0.10–0.20	0.30–0.61	0.025	0.025	0.10–0.30	0.50–0.81	0.44–0.65	...	...	
T5	0.15 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	...	...	
T5b	0.15 max	0.30–0.60	0.025	0.025	1.00–2.00	4.00–6.00	0.45 –0.65	...	...	
T5c	0.12 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	[Note (1)]	...	
T9	0.15 max	0.30–0.60	0.025	0.025	0.25–1.00	8.00–10.00	0.90–1.10	...	...	
T11	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50–1.00	1.00–1.50	0.44 –0.65	...	...	
T12 [Note (3)]	0.05 min–0.15 max	0.30–0.61	0.025	0.025	0.50 max	0.80–1.25	0.44–0.65	...	...	
T17	0.15–0.25	0.30–0.61	0.025	0.025	0.15–0.35	0.80–1.25	...	...	0.15	
T21	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50 max	2.65–3.35	0.80–1.06	...	...	
T22	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50 max	1.90–2.60	0.87–1.13	...	...	
T91	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.00–9.50	0.85–1.05	...	0.18–0.25	Cb 0.06–0.1 N 0.030–0.070 Ni 0.40 max Al 0.04 max
T92	0.07–0.13	0.30–0.60	0.020	0.010	0.50 max	8.50–9.50	0.30–0.60	...	0.15–0.25	W 1.5–2.00 Cb 0.04–0.09 B 0.001–0.006 N 0.03–0.07 Ni 0.40 max Al 0.04 max
18Cr-2Mo	0.025 max	1.00 max	0.040	0.030	1.00 max	17.5–19.5	1.75–2.50	[Note (2)]	...	N max 0.035 Ni + Cu max 1.00

NOTES:
(1) Grade T5c shall have a titanium content of not less than four times the carbon content and not more than 0.70%.
(2) Grade 18Cr-2Mo shall have Ti + Cb = 0.20 + 4 (C + N) min, 0.80 max.
(3) It is permissible to order T2 and T12 with 0.045 max Sulfur.

TABLE 2
CHEMICAL REQUIREMENTS OF AUSTENITIC STEEL

Grade	TP201	TP202	TP304	TP 304H	TP 304N	TP 304LN	TP 304L	TP 309Cb	TP 309H	TP 309HCb	TP 309S	TP 310Cb	TP 310H	TP 310HCb	TP 310HCbN
UNS Designation [Note (1)]	S20100	S20200	S30400	S30409	S30451	S30453	S30403	S30940	S30909	S30941	S30908	S31040	S31009	S31041	S31042
Carbon	0.15 max	0.15 max	0.08 max	0.04–0.10	0.08 max	0.035 max [Note (2)]	0.035 max [Note (2)]	0.08 max	0.04–0.10	0.04–0.10	0.08 max	0.08 max	0.04–0.10	0.04 0.10	0.04–0.10
Manganese, max	5.50–7.50	7.50–10.0	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Phosphorus, max	0.060	0.060	0.040	0.040	0.040	0.040	0.040	0.045	0.045	0.045	0.045	0.045	0.040	0.045	0.030
Sulfur, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Silicon	1.00 max	1.00 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max
Nickel	3.50–5.50	4.00–6.00	8.00–11.0	8.00–11.0	8.00–11.0	8.00–11.0	8.00–13.0	12.00–16.00	12.00–15.00	12.00–16.00	12.00–15.00	19.00–22.00	19.0–22.00	19.0–22.00	17.00–23.00
Chromium	16.0–18.0	17.0–19.0	18.0–20.0	18.0–20.0	18.0–20.0	18.0–20.0	18.0–20.0	22.00–24.00	22.00–24.00	22.00–24.00	22.00–24.00	24.00–26.00	24.00–26.00	24.00–26.00	24.00–26.00
Molybdenum	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	. . .	0.75 max	. . .
Titanium		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Columbium + tantalum	. . .	. . .	. . .	. . .	. . .	. . .	. . .	10 × C min, 1.10 max	. . .	10 × C min, 1.10 max	. . .	10 × C min, 1.10 max	. . .	10 × C min, 1.10 max	0.20–0.60
Tantalum, max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Nitrogen [Note (3)]	0.25 max	0.25 max	. . .	. . .	0.10–0.16	0.10–0.16	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.15–0.35
Cerium Others	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

TABLE 2 (CONT'D)
CHEMICAL REQUIREMENTS OF AUSTENITIC STEEL

Grade	TP 310S		TP316	TP 316H	TP316L	TP316N	TP316LN	TP317	TP317L	TP321	TP321H	TP347	TP347H	TP347LN
UNS Designation [Note (1)]	S31008	S31272	S31600	S31609	S31603	S31651	S31653	S31700	S31703	S32100	S32109	S34700	S34709	S34751
Carbon	0.08 max	0.08–0.12	0.08 max	0.04–0.10	0.035 max [Note (2)]	0.08 max	0.035 max [Note (2)]	0.08 max	0.035 max	0.08 max	0.04–0.10	0.08 max	0.04–0.10	0.005–0.020
Manganese, max	2.00	1.5–2.0	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Phosphorus, max	0.045	0.030	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Sulfur, max	0.030	0.015	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Silicon	0.75 max	0.3–0.7	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max
Nickel	19.00–22.00	14.0–16.0	11.0–14.0	11.0–14.0	10.0–15.0	11.0–14.0	11.0–14.0	11.0–14.0	11.0–15.0	9.00–13.0	9.00–13.0	9.00–13.0	9.00–13.0	9.00–13.0
Chromium	24.00–26.00	14.0–16.0	16.0–18.0	16.0–18.0	16.0–18.0	16.0–18.0	16.0–18.0	18.0–20.0	18.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0
Molybdenum	0.75 max	1.0–1.4	2.00–3.00	2.00–3.00	2.00–3.00	2.00–3.00	2.00–3.00	3.00–4.00	3.00–4.00	...	...	...	...	...
Titanium	...	0.3–0.6	...	...	...	...	...	...	...	[Note (4)]	[Note (5)]	...	...	...
Columbium + tantalum	...	...	...	...	...	...	...	...	...	...	...	[Note (6)]	[Note (7)]	0.2–0.5 [Note (8)]
Tantalum, max	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nitrogen [Note (3)]	...	...	...	...	...	0.10–0.16	0.10–0.16	...	...	...	...	...	...	0.06–0.10
Cerium	...	B 0.004–0.008	...		...	...	...	...	...	...	...	...	...	...
Others	...	...	...	...	...	...	...	...	...	...	...	...	...	...

TABLE 2 (CONT'D)
CHEMICAL REQUIREMENTS OF AUSTENITIC STEEL

Grade	TP347HFG	TP348	TP348H	XM-15								...	XM-19	
UNS Designation		S34800	S34809	S38100	S30615	S30815	S31050	S21500	S31725	S31726	S32615	S33228	S20910	S25700
Carbon	0.06–0.10	0.08 max	0.04–0.10	0.08 max	0.16–0.24	0.05–0.10	0.025	0.06–0.15	0.03 max	0.03 max	0.07 max	0.04–0.08	0.06 max	0.02 max
Manganese, max	2.00	2.00	2.00	2.00	2.00	0.80	2.00	5.50–7.0	2.00	2.00	2.00	1.00	4.00–6.00	2.0
Phosphorus, max	0.040	0.040	0.040	0.030	0.03	0.040	0.020	0.040	0.040	0.040	0.045	0.020	0.04	0.025
Sulfur, max	0.030	0.030	0.030	0.030	0.03	0.030	0.015	0.030	0.030	0.030	0.030	0.015	0.03	0.010
Silicon	0.75 max	0.75 max	0.75 max	1.50–2.50	3.2–4.0	1.40 2.00	0.4	0.2–1.0	0.75	0.75	4.8–6.0	0.30	1.00 max	6.5–8.0
Nickel	9.00–13.0	9.00–13.0	9.00–13.0	17.5–18.5	13.5–16.0	10.0–12.0	20.5–23.5	9.00–11.0	13.5–17.5	13.5–17.5	19.0–22.0	31.0–33.0	11.5–13.5	22.0–25.0
Chromium	17.0–20.0	17.0–20.0	17.0–20.0	17.0–19.0	17.0–19.5	20.0–22.0	24.0–26.0	14.0–16.0	18.0–20.0	17.0–20.0	16.5–19.5	26.0–28.0	20.5–23.5	8.0–11.0
Molybdenum		...	...	...	...	...	1.6–2.6	0.8–1.20	4.0–5.00	4.0–5.00	0.3–1.5	...	1.50–3.00	0.50 max
Titanium		...	...	...	...	...	...	...	...	...	...	...	...	...
Columbium + tantalum	8 × C-1.0	[Note (6)]	[Note (7)]	...	...	...	...	...	...	...	...	0.6–1.0	0.10–0.30	...
Tantalum, max		0.10	0.10	...	...	...	...	...	...	...	...	...	...	...
Nitrogen [Note (3)]		...	...	...	...	0.14–0.20	0.09–0.15	...	0.10 max	0.10–0.20	...	...	0.20–0.40	...
Cerium		...	...	...	...	0.03–0.08	...	...	...	...	...	0.05–0.10	...	...
Others		...	...	...	Al 0.8–1.5	...		Cb 0.75–1.25 V 0.15–0.40 B 0.003–0.009	Cu 0.75 max	Cu 0.75 max	Cu 1.5–2.5	Al 0.025 max	V 0.10–0.30	...

NOTES:
(1) New designation established in accordance with Practice E 527 and SAE J1086.
(2) For smaller diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040% is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes are those less than 0.049 in. [1.2 mm] in average wall thickness (0.044 in. [1.1 mm] in minimum wall thickness).
(3) The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
(4) Grade TP321 shall have a titanium content of not less than five times the carbon content and not more than 0.60%.
(5) Grade TP321H shall have a titanium content of not less than four times the carbon content and not more than 0.60%.
(6) Grades TP347 and TP348 shall have a columbium plus tantalum content of not less than ten times the carbon content and not more than 1.00%.
(7) Grades TP347H and TP348H shall have a columbium plus tantalum content of not less than eight times the carbon content and not more than 1.0%.
(8) Grade TP347LN shall have a columbium (niobium) plus tantalum content of not less than 15 times the carbon content.

TABLE 3
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE CONTINUOUS PROCESS OR BY DIRECT QUENCH AFTER HOT FORMING

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
2 in. [50.8 mm] and over in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

TABLE 4
TENSILE REQUIREMENTS

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, % [Note (1)(2)]
Ferritic Grades:				
T12	...	60 [415]	32 [220]	30
T91	...	85 [585]	60 [415]	20
T92	K92460	90 [620]	64 [440]	20
18Cr-2Mo	...	60 [415]	40 [275]	20
All other grades		60 [415]	30 [205]	30
Austenitic Grades:				
TP201	S20100	95 [655]	38 [260]	35
TP202	S20200	90 [620]	45 [310]	35
TP304	S30400	75 [515]	30 [205]	35
TP304H	S30409	75 [515]	30 [205]	35
TP304N	S30451	80 [550]	35 [240]	35
TP304L	S30403	70 [485]	25 [170]	35
TP304LN	S30453	75 [515]	30 [205]	35
TP309Cb	S30940	75 [515]	30 [205]	35
TP309H	S30909	75 [515]	30 [205]	35
TP309HCb	S30941	75 [515]	30 [205]	35
TP309S	S30908	75 [515]	30 [205]	35
TP310Cb	S31040	75 [515]	30 [205]	35
TP310H	S31009	75 [515]	30 [205]	35
TP310HCb	S31041	75 [515]	30 [205]	35
TP310HCbN	S31042	95 [655]	43 [295]	30
TP310S	S31008	75 [515]	30 [205]	35
	S31272	65 [450]	29 [200]	35
TP316	S31600	75 [515]	30 [205]	35
TP316H	S31609	75 [515]	30 [205]	35
TP316L	S31603	70 [485]	25 [170]	35
TP316N	S31651	80 [550]	35 [240]	35
TP316LN	S31653	75 [515]	30 [205]	35
TP317	S31700	75 [515]	30 [205]	35
TP317L	S31703	75 [515]	30 [205]	35
TP321	S32100	75 [515]	30 [205]	35
TP321H	S32109	75 [515]	30 [205]	35
TP347	S34700	75 [515]	30 [205]	35
TP347H	S34709	75 [515]	30 [205]	35
TP347HFG	...	80 [550]	30 [205]	35
TP348	S34800	75 [515]	30 [205]	35
TP348H	S34809	75 [515]	30 [205]	35
XM-15	S38100	75 [515]	30 [205]	35
...	S30615	90 [620]	40 [275]	35
...	S30815	87 [600]	45 [310]	40
...	S31050:			
t ≤ 0.25 in.		84 [580]	39 [270]	25
t > 0.25 in.		78 [540]	37 [255]	25
...	S33228	73 [500]	27 [185]	30
...	S21500	78 [540]	33 [230]	35
...	S31725	75 [515]	30 [205]	35
...	S31726	80 [550]	35 [240]	35
...	S32615	80 [550]	32 [220]	25
XM-19	S20910	100 [690]	55 [380]	35
...	S25700	78 [540]	35 [240]	50

(a) The following table gives the computed minimum values:

Wall Thickness		Elongation in 2 in. or 50 mm, min, % [Note (3)]	
in.	mm	18Cr-2Mo and T91	All Other Ferritic Grades
5/16 [0.312]	8	20	30
9/32 [0.281]	7.2	19	29
1/4 [0.250]	6.4	18	27
7/32 [0.219]	5.6	17	26
3/16 [0.188]	4.8	16	24
5/32 [0.156]	4	15	23
1/8 [0.125]	3.2	14	21
3/32 [0.094]	2.4	13	20
1/16 [0.062]	1.6	12	18
0.062 to 0.035, excl	1.6 to 0.9	12	17
0.035 to 0.022, excl	0.9 to 0.6	11	17
0.022 to 0.015 incl	0.6 to 0.4	11	16

GENERAL NOTES: The above table gives the computed minimum elongation values for each 1/32-in. [8-mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

Grade	Equation
18Cr-2Mo, T91, and T92	$E = 32t + 10.00$ [$E = 1.25t + 10.00$]
All other ferritic	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]

where:

E = elongation in 2 in. or 50 mm, %, and
t = actual thickness of specimen, in. [mm].

NOTES:
(1) When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimens with gage length equal to $4D$ (4 times the diameter) is used, the minimum elongation shall be 22% for all ferritic grades except 18Cr-2Mo and T91.
(2) For longitudinal strip tests a deduction from the basic minimum elongation values of 1.00 % for 18Cr-2Mo, T91, and T92 1.50 % for all other ferritic grades for each 1/32-in. [8-mm] decrease in wall thickness below 5/16 in. [8 mm] shall be made.
(3) Calculated elongation requirements shall be rounded to the nearest whole number.

SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED CARBON STEEL HEAT-EXCHANGER AND CONDENSER TUBES

SA-214/SA-214M

(Identical with ASTM Specification A 214/A 214M-90a)

1. Scope

1.1 This specification covers minimum-wall-thickness, electric-resistance-welded, carbon steel tubes to be used for heat exchangers, condensers, and similar heat-transfer apparatus.

1.2 The tubing sizes usually furnished to this specification are to 3 in. [76.2 mm] in outside diameter, inclusive. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 The purchaser shall specify in the order the outside diameter and minimum wall thickness. The inside diameter shall not be specified.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Document

2.1 *ASTM Standard:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (electric-resistance-welded tubes),

4.1.3 Size (outside diameter and minimum wall thickness),

4.1.4 Length (specific or random),

4.1.5 Optional requirements (Section 8 and 10.5),

4.1.6 Test report required (see Certification Section of Specification A 450/A 450M),

4.1.7 Specification designation, and

4.1.8 Special requirements.

5. Manufacture

5.1 Tubes shall be made by electric-resistance welding.

6. Heat Treatment

6.1 After welding, all tubes shall be heat treated at a temperature of 1650°F [900°C] or higher and followed by cooling in air or in the cooling chamber of a controlled atmosphere furnace. Cold drawn tubes shall be heat treated after the final cold-draw pass at a temperature of 1200°F [650°C] or higher.

7. Chemical Composition

7.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, %	0.18
Manganese, %	0.27–0.63
Phosphorus, max	0.035
Sulfur, max, %	0.035

7.2 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in 8.1 is not permitted.

8. Product Analysis

8.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube per 250 pieces; or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

8.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock, or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

NOTE — A lot consists of 250 tubes.

9. Hardness Requirements

9.1 The tubes shall have a hardness number not exceeding 72 HRB.

10. Mechanical Tests Required

10.1 *Flattening Test* — One flattening test shall be made on specimens from each of two tubes from each lot (Note) or fraction thereof.

10.2 *Flange Test* — One flange test shall be made on specimens from each of two tubes from each lot (Note) or fraction thereof.

10.3 *Reverse Flattening Test* — One reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

10.4 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot. The term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

10.5 *Hydrostatic or Nondestructive Electric Test* — Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

11. Surface Condition

11.1 The finished tubes shall be free of scale. A slight amount of oxidation shall not be considered as scale.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A 450/A 450M, the letters “ERW” shall be legibly stenciled on each tube, or marked on a tag attached to the bundle or box in which the tubes are shipped.

12.2 The manufacturer’s name or symbol may be placed permanently on each tube by rolling or light stamping before normalizing. If a single stamp is placed on the tube by hand, this mark should not be less than 8 in. [200 mm] from one end of the tube.

SPECIFICATION FOR STEEL CASTINGS, CARBON, SUITABLE FOR FUSION WELDING FOR HIGH-TEMPERATURE SERVICE

SA-216/SA-216M

(Identical with ASTM Specification A 216/A 216M-93 except for the addition of 2.3 and editorial differences in 2.1 and 10.1.) 98

1. Scope

1.1 This specification covers carbon steel castings for valves, flanges, fittings, or other pressure-containing parts for high-temperature service and of quality suitable for assembly with other castings or wrought-steel parts by fusion welding.

1.2 Three grades, WCA, WCB, and WCC, are covered in this specification. Selection will depend upon design and service conditions, mechanical properties, and the high temperature characteristics.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Applicable Documents

98 **2.1** *ASTM Standards:*

A 703 Specification for Steel Castings, General Requirements for Pressure-Containing Parts

E 165 Practice for Liquid Penetrant Examination

E 709 Guide for Magnetic Particle Examination

2.2 *Manufacturer's Standardization Society of the Valve and Fittings Industry Standard:*

SP 55 Steel Castings for Valve, Flanges, and Fittings, and Other Components (Visual Method)

2.3 *ASME Standard:*

ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the applicable requirements of Specification A 703/A 703M, including the supplementary requirements that are indicated on the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail. 98

4. Ordering Information 98

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing, dimensional tolerances shall be included on the casting drawing,

4.1.2 Grade of steel,

4.1.3 Options in the specification,

4.1.4 The supplementary requirements desired including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition.

5.2 Castings shall be furnished in the annealed, or normalized, or normalized and tempered condition unless Supplementary Requirement S15 is specified.

5.3 Heat treatment shall be performed after castings have been allowed to cool below the transformation range.

6. Temperature Control

6.1 Furnace temperatures for heat treating shall be effectively controlled by pyrometer.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Tensile Requirements

8.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 2.

9. Quality

9.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10 may be ordered.

9.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

10. Repair by Welding

10.1 Repairs shall be made using procedures and welders qualified under ASME Section IX.

10.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 $in.^2$ [65 cm^2], shall be radiographed to the same standards that are used to inspect the castings.

10.3 Castings containing any repair weld that exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or that exceeds approximately 10 $in.^2$ [65 cm^2] in area, or that was made to correct hydrostatic test defects, shall be stress relieved or heat-treated after welding. This mandatory stress relief or heat-treatment shall be in accordance with the procedure qualification used.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade WCA	Grade WCB	Grade WCC
Carbon, max	0.25[A]	0.30[B]	0.25[C]
Manganese, max	0.70[A]	1.00[B]	1.20[C]
Phosphorus, max	0.04	0.04	0.04
Sulfur, max	0.045	0.045	0.045
Silicon, max	0.60	0.60	0.60
Specified residual elements:			
Copper, max	0.30	0.30	0.30
Nickel, max	0.50	0.50	0.50
Chromium, max	0.50	0.50	0.50
Molybdenum, max	0.20	0.20	0.20
Vanadium, max	0.03	0.03	0.03
Total of these specified residual elements, max[D]	1.00	1.00	1.00

[A] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted up to a maximum of 1.10%.

[B] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% Mn above the specified maximum will be permitted up to a maximum of 1.28%.

[C] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted to a maximum of 1.40%.

[D] Not applicable when Supplementary Requirement S11 is specified.

TABLE 2
TENSILE REQUIREMENTS

	Grade WCA	Grade WCB	Grade WCC
Tensile strength, ksi [MPa]	60 to 85 [415 to 585]	70 to 95 [485 to 655]	70 to 95 [485 to 655]
Yield strength,[A] min, ksi [MPa]	30 [205]	36 [250]	40 [275]
Elongation in 2 in. [50 mm], min, %[B]	24	22	22
Reduction of area, min, %	35	35	35

[A] Determine by either 0.2% offset method or 0.5% extension-under-load method.

[B] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumberated in A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S2. Destruction Tests

S3. Bend Test

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S10. Examination of Weld Preparation.

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 709 or Practice E 165.

S11. Carbon Equivalent

S11.1 When specified on the order, the maximum carbon equivalent shall be:

Grade	Carbon, Equivalent, max
WCA	0.50
WCB	0.50
WCC	0.55

S11.2 Carbon equivalent (CE) shall be determined as follows:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

S15. Quench and Temper Heat-Treatment

SPECIFICATION FOR STEEL CASTINGS, MARTENSITIC STAINLESS AND ALLOY, FOR PRESSURE-CONTAINING PARTS, SUITABLE FOR HIGH-TEMPERATURE SERVICE

SA-217/SA-217M

(Identical with ASTM Specification A 217/A 217M-93 except for editorial changes in 2.2, 9.1, and 9.3). 98

1. Scope

1.1 This specification covers martensitic stainless steel and alloy steel castings for valves, flanges, fittings, and other pressure-containing parts (Note 1) intended primarily for high-temperature and corrosive service (Note 2).

1.2 One grade of martensitic stainless steel and eight grades of ferritic alloy steel are covered. Selection will depend on design and service conditions, mechanical properties, and the high-temperature and corrosion-resistant characteristics (Note 3).

NOTE 1 — Carbon steel castings for pressure-containing parts are covered by Specification A 216/A 216M. Low alloy quench-and-tempered grades equivalent to Specification A 217/A 217M grades may be found in both Specification A 352/A 352M and A 487/A 487M.

NOTE 2 — The grades covered by this specification represent materials that are generally suitable for assembly with other castings or wrought steel parts by fusion welding. It is not intended to imply that these grades possess equal degrees of weldability; therefore, it is the responsibility of the purchaser to establish for himself a suitable welding technique. Since these grades possess varying degrees of suitability for high-temperature and corrosion-resistant service, it is also the responsibility of the purchaser to determine which grade shall be furnished, due consideration being given to the requirements of the applicable construction codes.

NOTE 3 — The committee formulating this specification has included nine grades of materials that are considered to represent basic types of ferritic alloy steels suitable for valves, flanges, fittings, and other pressure-containing parts. Additional alloy steels that may better fulfill certain types of service will be considered for inclusion in this specification by the committee as the need becomes apparent.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 217 and SI units for materials ordered to Specification A 217M.

2. Referenced Documents

2.1 *ASTM Standards:* 98

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A 352/A 352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service

A 487/A 487M Specification for Steel Castings Suitable for Pressure Service

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination

E 165 Practice for Liquid Penetrant Inspection Method

E 709 Practice for Magnetic Particle Examination

98 **2.2** *ASME Standard:*
ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications

3. General Conditions for Delivery

98 **3.1** Material furnished to this specification shall conform to the applicable requirements of Specification A 703/A 703M, including any supplementary requirements that are indicated on the purchaser's order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

98 **4.1.2** Grade of steel,

4.1.3 Options in the specification, and

4.1.4 The supplementary requirements desired including the standards of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment proper to their design and chemical composition.

5.2 Castings shall be furnished in the normalized and tempered conditions; Grades WC1, WC4, WC5, WC6, and CA15 shall be tempered at 1100°F [595°C] min; Grades WC9, C5, C12, and WC11 shall be tempered at 1250°F [675°C] min.

5.3 Heat treatment shall be performed after castings have been allowed to cool below the transformation range.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Tensile Requirements

7.1 Steel used for the castings shall conform to the requirements as to tensile properties prescribed in Table 2.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free of adhering sand, scales cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperature are used in the removal of discontinuities, castings shall be preheated to at least the minimum temperatures in Table 3. 98

8.2 When additional inspection is desired, Supplementary Requirements S4, S5, and S10 may be ordered.

8.3 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair by Welding

9.1 Repairs shall be made using procedures and welders qualified under ASME Section IX.

9.2 Weld repairs shall be inspected to the same quality standards that are used to inspect the castings. When castings are produced with Supplementary Requirement S4 specified, weld repairs shall be inspected by magnetic particle examination to the same standards that are used to inspect castings. When castings are produced with Supplementary Requirement S5 specified, weld repairs on castings that have leaked on hydrostatic test, or on castings in which the depth of any cavity prepared for repair welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or on castings in which any cavity prepared for welding is greater than approximately 10 $in.^2$ [65 cm^2], shall be radiographed to the same standards that are used to inspect the castings.

9.3 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic test, or when the depth of the cavity prepared for welding exceeds 20% of the wall thickness or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 $in.^2$ [65 cm^2]. All castings with major repair welds shall be postweld heat treated or completely reheat-treated. This mandatory stress relief or reheat-treatment shall be in accordance with the qualified procedure used. Major repairs shall be inspected to the same quality standards that are used to inspect the castings.

TABLE 1
CHEMICAL REQUIREMENTS

NOTE — All values are maximum unless otherwise indicated.

	Composition, %								
	Carbon Molybdenum	Nickel Chromium Molybdenum	Nickel Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium Molybdenum	Chromium
Grade Identification Symbol	WC1	WC4	WC5	WC6	WC9	WC11	C5	C12	CA15
Carbon	0.25	0.05–0.20	0.05–0.20	0.05–0.20	0.05–0.18	0.15–0.21	0.20	0.20	0.15
Manganese	0.50–0.80	0.50–0.80	0.40–0.70	0.50–0.80	0.40–0.70	0.50–0.80	0.40–0.70	0.35–0.65	1.00
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.020	0.04	0.04	0.040
Sulfur	0.045	0.045	0.045	0.045	0.045	0.015	0.045	0.045	0.040
Silicon	0.60	0.60	0.60	0.60	0.60	0.30–0.60	0.75	1.00	1.50
Nickel	. . .	0.70–1.10	0.60–1.00	. . .	. . .	. . .	. . .	. . .	1.00
Chromium	. . .	0.50–0.80	0.50–0.90	1.00–1.50	2.00–2.75	1.00–1.50	4.00–6.50	8.00–10.00	11.5–14.0
Molybdenum	0.45–0.65	0.45–0.65	0.90–1.20	0.45–0.65	0.90–1.20	0.45–0.65	0.45–0.65	0.90–1.20	0.50
Aluminum	. . .	. . .	. . .	. . .	. . .	0.01	. . .	. . .	. . .
	Specified Residual Elements								
Copper	0.50	0.50	0.50	0.50	0.50	0.35	0.50	0.50	. . .
Nickel	0.50	. . .	. . .	0.50	0.50	0.50	0.50	0.50	. . .
Chromium	0.35	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Tungsten	0.10	0.10	0.10	0.10	0.10	. . .	0.10	0.10	. . .
Vanadium	. . .	. . .	. . .	. . .	. . .	0.03	. . .	. . .	. . .
Total content of these residual elements	1.00	0.60	0.60	1.00	1.00	1.00	1.00	1.00	. . .

TABLE 2
TENSILE REQUIREMENTS

Grade	Tensile Strength, ksi [MPa]	Yield Strength,[A] min, ksi [MPa]	Elongation in 2 in. [50 mm] min, %[B]	Reduction of Area, min, %
WC1	65 [450] to 90 [620]	35 [240]	24	35
WC4, WC5, WC6, WC9	70 [485] to 95 [655]	40 [275]	20	35
WC11	80 [550] to 105 [725]	50 [345]	18	45
C5, C12	90 [620] to 115 [795]	60 [415]	18	35
CA15	90 [620] to 115 [795]	65 [450]	18	30

[A] Determine by either 0.2% offset method or 0.5% extension-under-load method.
[B] When ICI test bars are used in tensile testing as provided for in Specification A 703/A 703M, the gage length to reduced section diameter ratio shall be 4 to 1.

TABLE 3
MINIMUM PREHEAT TEMPERATURES

Grade	Thickness, in. [mm]	Minimum Preheat Temperature, °F [°C]
WC1	$\frac{5}{8}$ and under	50 [10]
	Over $\frac{5}{8}$ [15.9]	250 [120]
WC4	All	300 [150]
WC5	All	300 [150]
WC6	All	300 [150]
WC9	All	400 [200]
WC11	All	300 [150]
C5	All	400 [200]
C12	All	400 [200]
CA15	All	400 [200]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S2. Destruction Tests

S3. Bend Tests

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 165 or Practice E 709.

S13. Hardness Test

S21. Heat Treatment Furnace Record

S22. Heat Treatment

S51. Mandatory Postweld Heat Treatment

S51.1 All castings with repair welds shall receive a mandatory thermal stress relief or complete reheat treatment in accordance with the qualified procedure after all weld repairs.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, MANGANESE-VANADIUM-NICKEL

SA-225/SA-225M

(Identical with ASTM Specification A 225/A 225M-93.)

1. Scope

1.1 This specification covers manganese-vanadium-nickel alloy steel plates intended primarily for welded layered pressure vessels.

1.2 Material under this specification is available in two grades having different strength levels as follows:

Grade	Tensile Strength, ksi [MPa]
C	105–135 [725–930]
D	
3 in. [75 mm] and under	80–105 [550–725]
Over 3 in. [75 mm]	75–100 [515–690]

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements; however, current mill practice normally limits Grade C to 0.58 in. [15 mm] maximum and Grade D to 6 in. [150 mm] maximum.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the basis of purchase that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 Grade D plates of all thicknesses and Grade C plates of thicknesses over 2 in. [50 mm] shall be normalized.

5.2 Grade C plates 2 in. [50 mm] and under in thickness are usually supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1, unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements* — The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.2 For plates with a nominal thickness of $^{3}/_{4}$ in. [20 mm] and under, the $1^{1}/_{2}$ in. [40 mm] wide rectangular specimen may be used and the elongation determined in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %	
	Grade C	Grade D
Carbon, max[A]	0.25	0.20
Manganese, max:		
Heat analysis	1.60	1.70
Product analysis	1.72	1.84
Phosphorus, max[A]	0.035	0.035
Sulfur, max[A]	0.035	0.035
Silicon:		
Heat analysis	0.15–0.40	0.10–0.50
Product analysis	0.13–0.45	0.08–0.56
Vanadium:		
Heat analysis	0.13–0.18	0.10–0.18
Product analysis	0.11–0.20	0.08–0.20
Nickel:		
Heat analysis	0.40–0.70	0.40–0.70
Product analysis	0.37–0.73	0.37–0.73

[A] Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

	Grade C		Grade D	
	ksi	[MPa]	ksi	[MPa]
Tensile strength				
All thicknesses	105–135	[725–930]		
3 in. [75 mm] and under			80–105	[550–725]
Over 3 in. [75 mm]			75–100	[515–690]
Yield strength, min[B]				
All thicknesses	70	[485]	60	[415]
3 in. [75 mm] and under			55	[380]
Over 3 in. [75 mm]				
Elongation in 8 in. [200 mm], min, %			. . .	
Elongation in 2 in. [50 mm], min, %	20[A]		19	
Elongation in 5D, min, %			17	

[A] See Specification A 20/A 20M.
[B] Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those which are considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in Accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in Accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in Accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED CARBON STEEL BOILER AND SUPERHEATER TUBES FOR HIGH-PRESSURE SERVICE

SA-226/SA-226M

(Identical with ASTM Specification A 226/A 226M-95)

1. Scope

1.1 This specification covers minimum-wall-thickness, electric-resistance-welded, carbon steel, boiler and superheater tubes for high-pressure service.

1.2 The tubing sizes and thickness usually furnished to this specification are ½ in. to 5 in. [12.7 to 127 mm] in outside diameter and 0.085 to 0.360 in. [2.2 to 9.1 mm] inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520 shall supplement and supersede the requirements of this specification.

1.5 An optional supplementary requirements is provided and, when desired, shall be so stated in the order.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

NOTE 1 *Explanatory Note* — For purposes of design, the following tensile properties may be assumed:

Tensile strength, min, ksi [MPa]	47 [325]
Yield strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (electric-resistance-welded tubes),

4.1.3 Size (outside diameter and minimum wall thickness),

4.1.4 Length (specific or random),

4.1.5 Optional requirements (Section on Product Analysis and Hydrostatic or Nondestructive Electric Test),

4.1.6 Test report required (see Certification Section of Specification A 450/A 450M),

4.1.7 Specification designation, and

4.1.8 Special requirements and any supplementary requirements selected.

5. Manufacture

5.1 The steel shall be killed.

5.2 The tubes shall be made by electric-resistance welding.

6. Heat Treatment

6.1 After welding all tubes shall be heat treated at a temperature of 1650°F [900°C] or higher and followed by cooling in air or in the cooling chamber of a controlled atmosphere furnace. Cold drawn tubes shall be heat treated after the final cold draw pass at a temperature of 1200°F [650°C] or higher.

7. Chemical Composition

7.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, %	0.06 to 0.18
Manganese, %	0.27 to 0.63
Phosphorus, max, %	0.035
Sulphur, max, %	0.035
Silicon, max, %	0.025

7.2 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in 7.1 is not permitted.

8. Hardness Requirements

8.1 The tubes shall have a hardness not exceeding 125 HB or 72 HRB.

9. Product Analysis

9.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube per 100 pieces for sizes over 3 in. [76.2 mm] and one tube per 250 pieces for sizes 3 in. [76.2 mm] and under; or when identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

9.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of the specification shall be rejected.

NOTE 2 — A lot consists of 250 tubes for sizes 3 in. [76.2 mm] and under and of 100 tubes for sizes over 3 in. [76.2 mm], prior to cutting to length.

10. Mechanical Test Required

10.1 *Flattening Test* — One flattening test shall be made on specimens from each of two tubes from each lot (Note 2) of fraction thereof.

10.2 *Flange Test* — One flange test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

10.3 *Reverse Flattening Test* — One reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

10.4 *Hardness Test* — Brinell or Rockwell hardness determination shall be made on specimens from two tubes from each lot. The term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type

furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

10.5 *Hydrostatic or Nondestructive Electric Test* — Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which is to be used.

11. Forming Operations

11.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws or opening at the weld. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A 450/A 450M, the letters “ERW” shall be legibly stenciled on each tube or marked on a tag attached to the bundle or box in which the tubes are shipped.

SUPPLEMENTARY REQUIREMENT

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order. Details of this supplemental requirement shall be agreed upon by the manufacturer and the purchaser.

S1. Additional Testing of Welded Tubing per ASME Request

S1.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 450/A 450M.

S1.2 If Practice E 273 is employed, a 100% volumetric inspection of the entire length of each tube shall also be performed using one of the non-destructive electric tests permitted by Specification A 450/A 450M.

S1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S1.4 In addition to the marking prescribed in Specification A 450/A 450M, S1 shall be added after the grade designation.

SPECIFICATION FOR CHROMIUM-VANADIUM ALLOY STEEL VALVE SPRING QUALITY WIRE

SA-232/SA-232M

(Identical with ASTM Specification A 232/A 232M-91.)

1. Scope

1.1 This specification covers the highest quality of round chromium-vanadium alloy steel valve spring wire, uniform in quality and temper, intended for the manufacture of valve springs and other springs requiring high-fatigue properties when used at moderately elevated temperatures. This wire shall be either in the annealed and cold-drawn or oil-tempered condition as specified by the purchaser.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *ANSI Standard:*

B32.4 Preferred Metric Sizes for Round, Square, Rectangle, and Hexagon Metal Products

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.4 *Military Standard:*

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

3. Ordering Information

3.1 Orders for material under this specification should include the following information for each ordered item:

3.1.1 Quantity (mass),

3.1.2 Name of material (chromium-vanadium alloy steel valve spring quality wire),

3.1.3 Dimensions (Table 1 and Section 8),

3.1.4 Condition (Section 6),

3.1.5 Packaging (Section 14),

3.1.6 Heat analysis report, if requested (Section 5.2),

3.1.7 Certification or test report, or both, if specified (Section 13), and

3.1.8 ASTM designation and year of issue.

NOTE 1 — A typical ordering description is as follows: 20 000 kg oil-tempered chromium-vanadium alloy steel valve spring quality wire, size 6.00 mm in 150 kg coils to ASTM A 232/A 232M dated _____, or for inch-pound units, 40 000 lb oil-tempered chromium-vanadium alloy steel valve spring quality wire, size 0.250 in. in 350-lb coils to ASTM A 232/A 232M dated _____.

4. Materials and Manufacture

4.1 The steel may be made by any commercially accepted steel making process. The steel may be either ingot cast or strand cast.

4.2 The finished wire shall be free from detrimental pipe and undue segregation.

5. Chemical Requirements

5.1 The steel shall conform to the requirements for chemical composition specified in Table 2.

5.2 *Heat Analysis* — Each heat of steel shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 2. This analysis shall be made from a test specimen preferably taken during the pouring of the heat. When requested, this shall be reported to the purchaser and shall conform to the requirement of Table 2.

5.2 *Product Analysis* — An analysis may be made by the purchaser from finished wire representing each heat of steel. The average of all the separate determinations made shall be within the limits specified in the analysis column. Individual determinations may vary to the extent shown in the product analysis tolerance column, except that the several determinations of a single element in any one heat shall not vary both above and below the specified range.

5.4 For referee purposes, Test Methods, Practices and Terminology A 751 shall be used.

6. Mechanical Requirements

6.1 *Annealed and Cold Drawn* — When purchased in the annealed and cold-drawn condition, the wire shall have been given a sufficient amount of cold working to meet the purchaser's coiling requirements and shall be in a suitable condition to respond properly to heat treatment. In special cases the hardness, if desired, shall be stated in the purchase order.

6.2 *Oil Tempered* — When purchased in the oil-tempered condition, the tensile strength and minimum percent reduction of area, sizes 2.50 mm [0.105 in.] and coarser, of the wire shall conform to the requirements prescribed in Table 1.

6.2.1 *Number of Tests* — One test specimen shall be taken for each five coils, or fraction thereof, in a lot. Each heat in a given lot shall be tested.

6.2.2 *Location of Tests* — Test specimens shall be taken from either end of the coil.

6.2.3 *Test Method* — The tension test shall be made in accordance with Test Methods and Definitions A 370.

6.3 *Wrap Test:*

6.3.1 Oil-tempered or cold-drawn wire 4.00 mm [0.162 in.] and smaller in diameter shall wind on itself as an arbor without breakage. Larger diameter wire up to and including 8.00 mm [0.312 in.] in diameter shall wrap without breakage on a mandrel twice the wire diameter. The wrap test is not applicable to wire over 8.00 mm [0.312 in.] in diameter.

6.3.2 *Number of Tests* — One test specimen shall be taken for each five coils or fraction thereof, in a lot. Each heat in a given lot shall be tested.

6.3.3 *Location of Test* — Test specimens shall be taken from either end of the coil.

6.3.4 *Test Method* — The wrap test shall be made in accordance with Test Methods and Definitions A 370.

7. Metallurgical Requirements

7.1 *Surface Condition:*

7.1.1 The surface of the wire as received shall be free of imperfections such as pits, die marks, scratches, seams, and other defects tending to impair the fatigue value of the springs.

7.1.2 *Number of Tests* — One test specimen shall be taken from each end of every coil.

7.1.3 *Test Method* — The surface shall be examined after etching in a solution of equal parts of hydrochloric acid and water that has been heated to approximately 80°C for a sufficient length of time to remove up to approximately 1% of the diameter of the wire. Test ends shall be examined using 10× magnification.

7.2 *Decarburization:*

7.2.1 Transverse sections of the wire properly mounted, polished, and etched shall show no completely decarburized (carbon-free) areas when examined at a magnification of 100 diameters. Partial decarburization shall not exceed a depth of 0.025 mm [0.001 in.] on wire 5.00 mm [0.192 in.] and smaller or 0.038 mm [0.0015 in.] on larger than 5.00 mm [0.192 in.].

7.2.2 To reveal the decarburization more accurately in the untempered wire, the specimen shall be hardened and tempered before microscopical examination. Prior

to hardening, the specimen shall be filed flat on one side enough to reduce the diameter at least 20%. The subsequent mounted specimen shall show the flattened section, as well as the original wire edge. Any decarburization on this flattened section shall necessitate a new specimen for examination.

7.2.3 *Number of Tests* — One test specimen shall be taken for each five coils, or fraction thereof, in a lot. Each in a given lot shall be tested.

7.2.4 *Location of Tests* — Test specimens may be taken from either end of the coil.

8. Dimensions and Permissible Variations

8.1 The permissible variations in the diameter of the wire shall be specified in Table 3.

8.2 *Number of Tests* — One test specimen shall be taken from each end of every coil.

9. Workmanship, Finish, and Appearance

9.1 *Annealed and Cold Drawn* — The wire shall not be kinked or improperly cast. To test for cast, a few convolutions of wire shall be cut loose from the coil and placed on a flat surface. The wire shall lie substantially flat on itself and not spring up nor show a wavy condition.

9.2 *Oil Tempered* — The wire shall be uniform in quality and temper and shall not be wavy or crooked.

9.3 Each coil shall be one continuous length of wire properly coiled and firmly tied.

9.4 No welds are permitted in the finished product and any welds made during processing must be removed.

10. Retests

10.1 If any test specimen exhibits obvious defects it may be discarded and another specimen substituted.

11. Inspection

11.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified in this specification. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

12. Rejection and Rehearing

12.1 Unless otherwise specified, any rejection based on tests made in accordance with these specifications shall be reported to the manufacturer as soon as possible so that an investigation may be initiated.

12.2 The material must be adequately protected and correctly identified in order that the manufacturer may make a proper investigation.

13. Certification

13.1 When specified in the purchase order or contract, a manufacturer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

13.2 The certification shall include the specification number, year date of issue, and revision letter, if any.

14. Packaging, Marking, and Loading for Shipment

14.1 The coil mass, dimensions, and the method of packaging shall be agreed upon between the manufacturer and purchaser.

14.2 The size of the wire, purchaser's order number, ASTM specification number, heat number, and name or mark of the manufacturer shall be marked on a tag securely attached to each coil of wire.

14.3 Unless otherwise specified in the purchaser's order, packaging, marking, and loading for shipments shall be in accordance with those procedures recommended by Practice A 700.

14.4 *For Government Procurement* — Packaging, packing, and marking of material for military procurement shall be in accordance with the requirements of MIL-STD-163, Level A, Level C, or commercial as specified in the contract or purchase order. Marking for shipment of material for civil agencies shall be in accordance with Fed. Std. No. 123.

TABLE 1
TENSILE REQUIREMENTS[A]
SI Units

Diameter[B] mm	MPa, min	MPa, max	Reduction of Area, min, %
0.50	2060	2260	C
0.55	2050	2240	C
0.60	2030	2220	C
0.65	2010	2200	C
0.70	2000	2160	C
0.80	1980	2140	C
0.90	1960	2120	C
1.00	1940	2100	C
1.10	1920	2080	C
1.20	1900	2060	C
1.40	1860	2020	C
1.60	1820	1980	C
1.80	1800	1960	C
2.00	1780	1930	C
2.20	1750	1900	C
2.50	1720	1860	45
2.80	1680	1830	45
3.00	1660	1800	45
3.50	1620	1760	45
4.00	1580	1720	40
4.50	1560	1680	40
5.00	1520	1640	40
5.50	1480	1620	40
6.00	1460	1600	40
6.50	1440	1580	40
7.00	1420	1560	40
8.00	1400	1540	40
9.00	1380	1520	40
10.00	1360	1500	40
11.00	1340	1480	40
12.00	1320	1460	40

Inch-Pound Units

Diameter, in.	ksi, min	ksi, max	Reduction of Area, min, %
0.020	300	325	C
0.032	290	315	C
0.041	280	305	C
0.054	270	295	C
0.062	265	290	C
0.080	255	275	C
0.105	245	265	45
0.135	235	255	45
0.162	225	245	40
0.192	220	240	40
0.244	210	230	40
0.283	205	225	40
0.312	203	223	40
0.375	200	220	40
0.438	195	215	40
0.500	190	210	40

[A] Tensile strength values for intermediate diameters may be interpolated.
[B] Preferred sizes. For a complete list, refer to ANSI B32.4.
[C] The reduction of area test is not applicable to wire under 2.50 mm [0.105 in.] in diameter.

TABLE 2
CHEMICAL REQUIREMENTS

	Analysis, %	Product Analysis Tolerance, %
Carbon	0.48–0.53	±0.02
Manganese	0.70–0.90	±0.03
Phosphorus	0.020 max	+0.005
Sulfur	0.035 max	+0.005
Silicon	0.15–0.35	±0.02
Chromium	0.80–1.10	±0.05
Vanadium	0.15 min	−0.01

TABLE 3
PERMISSIBLE VARIATIONS IN WIRE DIAMETER[A]
SI Units

Diameter, mm	Permissible Variations, plus and minus, mm	Permissible Out-of-Round, mm
to 2.0, incl	0.02	0.02
Over 2.0 to 4.00, incl	0.03	0.03
Over 4.00 to 9.00, incl	0.04	0.04
Over 9.00	0.05	0.05

Inch-Pound

Diameter, in.	Permissible Variations, plus and minus, in.	Permissible Out-of-Round, in.
0.020 to 0.075, incl	0.0008	0.0008
Over 0.075 to 0.148, incl	0.001	0.001
Over 0.148 to 0.375, incl	0.0015	0.0015
Over 0.375 to 0.500, incl	0.002	0.002

[A] For purposes of determining conformance with this specification, all specified limits are absolute as defined in Practice E 29.

SPECIFICATION FOR PIPING FITTINGS OF WROUGHT CARBON STEEL AND ALLOY STEEL FOR MODERATE AND ELEVATED TEMPERATURES

SA-234/SA-234M

(Identical with ASTM Specification A 234/A 234M-95a.) 98

1. Scope

1.1 This specification covers wrought carbon steel and alloy steel fittings of seamless and welded construction covered by the latest revision of ANSI B16.9, ANSI B16.11, ANSI B16.28, MSS SP-79, and MSS SP-95. These fittings are for use in pressure piping and in pressure vessel fabrication for service at moderate and elevated temperatures. Fittings differing from these ANSI and MSS standards shall be furnished in accordance with Supplementary Requirement S9.

1.2 Optional supplementary requirements are provided for fittings where a greater degree of examination is desired. When desired, one or more of these supplementary requirements may be specified in the order.

1.3 This specification does not cover cast welding fittings or fittings machined from castings. Cast steel welding fittings are governed by Specifications A 216/A 216M and A 217/A 217M.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts Suitable for High-Temperature Service

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 165 Practice for Liquid Penetrant Inspection Method

E 709 Practice for Magnetic Particle Examination

2.2 *ANSI Standards:*

B16.9 Steel Butt-Welding Fittings

B16.11 Forged Steel Fittings, Socket Welding and Threaded

B16.28 Wrought Steel Butt-Welding Short Radius Elbows and Returns

2.3 *ASME Boiler and Pressure Vessel Code:*

Section V Nondestructive Examination

Section VIII, Division 1, Pressure Vessels

Section IX Welding Qualifications

2.4 *MSS Standards:*

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions

MSS SP-79 Socket Welding Reducer Inserts

MSS SP-95 Swage (d) Nipples and Bull Plugs

2.5 *ASNT Standard:*

SNT-TC-1A(1984) Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity (number of fittings of each kind),

3.1.2 Description of fitting and nominal dimensions (standard or special),

3.1.3 Steel composition by grade and class designation,

3.1.4 Construction, seamless or welded (unless seamless or welded construction is specified by the purchaser either may be furnished at the option of the supplier),

3.1.5 Additional requirements, if any, (See 17.5), and

3.1.6 Supplementary requirements, if any.

4. Materials

4.1 The material for fittings shall consist of killed steel, forgings, bars, plates, seamless or fusion-welded tubular products with filler metal added and shall conform to the chemical requirements of Table 1. Unless otherwise specified for carbon steel plates, the steel may be made to either coarse grain or fine grain practice.

4.2 A starting material specification that specifically requires the addition of any element beyond those listed for the materials in Tables 1 and 2 and for the applicable grade of material is not permitted. This does not preclude the use of deoxidizers or the judicious use of elements for grain size control.

5. Manufacture

5.1 Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious imperfections in the fittings.

5.2 Fittings machined from bar shall be restricted to NPS 4 or smaller. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

NOTE 1 — Fittings NSP-4 and under may be machined from hot-forged or rolled, cold-sized, and straightened bar stock having the chemical composition of the grade in Table 1 and the mechanical properties of the Grade in Table 2. Heat treatment shall be in accordance with Section 6. All caps machined from bar stock shall be examined with by liquid penetrant or magnetic particle in accordance with S3 or S4.

5.3 All welds including welds in tubular products from which fittings are made shall be (*1*) made by welders, welding operators, and welding procedures qualified under the provisions of ASME Section IX, (*2*) heat treated in accordance with Section 6 of this specification, and (*3*) radiographically examined throughout the entire length of each weld in accordance with Article 2, ASME Section V with acceptance limits in accordance with Paragraph UW-51 of ASME Section VIII, Division 1 of the ASME Boiler Pressure Vessel Code. In place of radiographic examination, welds may be ultrasonically examined in accordance with Appendix 12 of Section VIII. The NDE of welds in Grades WPB, WPC, WP1, WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, WP12 Class 2, and WPR may be performed either prior to or after forming. NDE of welds in Grades WP5, WP9, WP91, WP22 Class 1, and WP22 Class 3 shall be done after forming.

5.4 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

5.5 The welded joints of the fittings shall be finished in accordance with the requirements of Paragraph UW-35 (*a*) of ASME Section VIII, Division 1.

5.6 All butt-weld tees manufactured by cold-forming method(s) shall be liquid penetrant or magnetic particle examined by one of the methods specified in Supplementary Requirement S3 or S4. This examination shall be performed after final heat treat. Only the side wall area of the tees need be examined. This area is defined by a circle that covers the area from the weld bevel of the branch outlet to the center line of the body or run. Internal and external surfaces shall be examined when size permits accessibility. No cracks shall be permitted. Other imperfections shall be treated in accordance with Section 12 on Surface Quality. After the removal of any crack, the tee(s) shall be re-examined by the original method. Acceptable tees shall be marked with the symbol PT or MT, as applicable, to indicate compliance.

6. Heat Treatment

6.1 *Heat Treatment Procedures* — Fittings, after forming at an elevated temperature, shall be cooled to a temperature below the critical range under suitable conditions to prevent injuries by too rapid cooling, but in no case more rapidly than the cooling rate in still air. Heat-treated fittings shall be treated according to the following procedures:

6.1.1 *Full Annealing* — Fittings shall be uniformly reheated to a temperature above the transformation range and after being held for a sufficient time at this temperature, cooled slowly to a temperature below the transformation range.

6.1.2 *Isothermal Annealing* — Isothermal annealing as applied to fittings shall involve austenitizing a ferrous alloy and then cooling to and holding within the range of temperature at which the austenite transforms to a relatively soft ferrite-carbide aggregate.

6.1.3 *Normalizing* — Fittings shall be uniformly reheated to a temperature above the transformation range and subsequently cooled in air at room temperature.

6.1.4 *Tempering and Post-Weld Heat Treatment* — Fittings shall be reheated to the prescribed temperature below the transformation range, held at temperature for the greater of ½ h or 1 h/in. [2.4 min/mm] of thickness at the thickest section and cooled in the furnace or in still air.

6.1.5 *Stress Relieving* — Fittings shall be uniformly heated; temperature shall not vary by more than ±25°F [±14°C] from the selected stress relieving temperature.

6.2 *WPB, WPC, and WPR Fittings:*

6.2.1 Hot-formed WPB, WPC, and WPR fittings upon which the final forming operation is completed at a temperature above 1150°F [620°C] and below 1800°F [980°C] need not be heat treated provided they are cooled in still air. If the manufacturer elects to heat treat such fittings, it shall be by one of the procedures defined in 6.1 through 6.1.4.

6.2.2 Hot-formed or forged WPB, WPC, and WPR fittings finished at temperature in excess of 1800°F [980°C] shall subsequently be annealed, normalized, or normalized and tempered. Hot-forged fittings NPS 4 or smaller need not be heat treated.

6.2.3 WPB, WPC, and WPR fittings produced by locally heating a portion of the fitting stock to any temperature for forming shall be subsequently annealed, normalized, or normalized and tempered. Fittings such as elbows, tees, header tees, reducers and lap joint stub ends, NPS 12 and under, shall not require heat treatment after forming a locally heated portion of the fitting.

6.2.4 Cold-formed WPB, WPC, and WPR fittings, upon which the final forming operation is completed at a temperature below 1150°F [620°C] shall be normalized, or shall be stress relieved at 1100 to 1275°F [595 to 690°C].

6.2.5 WPB, WPC, and WPR fittings produced by fusion welding and having a nominal wall thickness at the welded joint of ¾ in. [19 mm] or greater shall be post-weld heat treated at 1100 to 1250°F [595 to 674°C], or in accordance with 6.2.6.

6.2.6 At the option of the manufacturer, WPB and WPC fittings produced by any of the methods in Section 5 may be annealed, normalized, or normalized and tempered.

6.3 *Fittings Other than WPB, WPC, and WPR:*

6.3.1 Fittings of Grades WP1, WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, WP12 Class 2, WP22 Class 1, WP22 Class 3, WP5, and WP9 shall be furnished in the full-annealed, isothermal-annealed, or normalized and tempered condition. If normalized and tempered, the tempering temperature for WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, and WP12 Class 2 shall not be less than 1150°F [620°C]; for Grades WP5, WP9, WP22 Class 1, and WP22 Class 3 the tempering temperature shall not be less than 1250°F [675°C].

6.3.2 Fittings of Grades WP1 or WP12 Class 2 either hot formed or cold formed may be given a final heat treatment at 1200°F [650°C] instead of the heat treatment specified in 6.3.1.

6.3.3 Fittings in all thicknesses produced by fusion welding after the heat treatment specified in 6.3.1 shall be post-weld heat treated at a temperature not less than prescribed above for tempering except that Grade WP1 is required to be post-weld heat treated only when the nominal wall thickness at the welded joint is ½ in. [13 mm] or greater.

6.3.4 Except when Supplementary Requirement S12 is specified by the purchaser, Grade WP91 shall be normalized at 1900°F [1040°C] minimum, and 2000°F [1095°C] maximum, and tempered at 1350°F [730°C] minimum as a final heat treatment.

6.4 *WPB and WPC Fittings Made from Bar* — Cold-finished bars reduced in cross-sectional area more than 10% by cold drawing or cold rolling are not acceptable

for use in the manufacture of these fittings unless the bars have been either stress relieved in the temperature range of 1100 to 1250°F [595 to 675°C], normalized, normalized and tempered, or fully annealed. Mechanical testing must be performed subsequent to the final heat-treating operation.

6.5 Liquid quenching followed by tempering shall be permitted for all grades when approved by the purchaser. Minimum tempering temperature shall be 1100°F [595°C] for WPB, WPC, and WPR, 1150°F [620°C] for Grades WP1, WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, and WP12 Class 2 and 1250°F [675°C] for Grades WP5, WP9, WP22 Class 1, and WP22 Class 3, and 1350°F [730°C] for Grade WP91.

7. Chemical Composition

7.1 The chemical composition of each cast or heat used shall be determined and shall conform to the requirements of the chemical composition for the respective materials listed in Table 1. The ranges as shown have been expanded to include variations of the chemical analysis requirements that are listed in the various specifications for the starting materials (pipe, tube, plate, bar, and forgings) normally used in the manufacturing of fittings to this specification. Test Methods, Practices, and Terminology A 751 shall apply.

7.2 Weld metal used in the construction of carbon-steel fittings shall be mild steel analysis No. A1 of Table QW-442, Section IX of the ASME Boiler and Pressure Vessel Code; No. A2 may be used for Grade WPCW.

7.3 The molybdenum and chromium content of the deposited weld metal of alloy steel fittings shall be within the same percentage range as permitted for the base metal.

8. Tensile Requirements

8.1 The tensile properties of the fitting material shall conform to the requirements listed in Table 2. The testing shall be performed in accordance with Test Methods and Definitions A 370.

8.1.1 Specimens cut either longitudinally or transversely shall be acceptable for the tension test.

8.1.2 While Table 2 specifies elongation requirement for both longitudinal and transverse specimens, it is not the intent that both requirements apply simultaneously. Instead, it is intended that only the elongation requirement that is appropriate for the specimen used be applicable.

8.2 One tension test shall be made on each heat of material and in the same condition of heat treatment as the finished fittings it represents. The sample thickness shall not vary more than $\frac{1}{4}$ in. [6 mm] from the fitting wall thickness it represents.

8.3 When cold-formed fittings are furnished, samples of the raw material shall be normalized or stress relieved as required in 6.2.4. Tension tests conducted on these heat-treated samples shall be considered to be the tensile properties of the cold-formed fittings.

8.4 Records of the tension tests shall be certification that the material of the fitting meets the tensile requirements of this specification provided the heat treatments are the same. If the raw material was not tested, or the fitting is not in the same condition of heat treatment, the fitting manufacturer shall perform the required test on material representative of the finished fitting from each heat of starting material.

9. Hardness

9.1 Fittings shall be capable of meeting the following hardness requirements, if tested:

9.1.1 Fittings of Grades WP5, WP9, and WPR — 217 HB maximum.

9.1.2 Fittings of Grade WP91 — 248 HB maximum.

9.1.3 Fittings of all other grades — 197 HB maximum.

9.2 When actual hardness testing of the fittings is required, see Supplementary Requirement S8.

10. Hydrostatic Tests

10.1 Hydrostatic testing is not required by this specification.

10.2 All fittings shall be capable of withstanding without failure, leakage, or impairment of their serviceability, a hydrostatic test pressure equal to that prescribed for the specified matching pipe of equivalent material.

11. Dimensions

11.1 Butt-welding fittings and butt-welding short radius elbows and returns purchased in accordance with this specification shall conform to the dimensions and tolerances given in the latest revision of ANSI B16.9 and B16.28, respectively. Steel socket-welding and threaded fittings purchased in accordance with this specification shall conform to the sizes, shapes, dimensions, and tolerances specified in the latest revision of ANSI B16.11 or MSS SP-79.

11.2 Fittings of size or shape differing from these standards, but meeting all other requirements of this specification may be furnished in accordance with Supplementary Requirement S9.

12. Surface Quality

12.1 Fittings supplied under this specification shall be examined visually. Selected typical surface discontinuities shall be explored for depth. The fittings shall be free of surface discontinuities that penetrate more than 5% of the specified nominal wall thickness, except as defined in 12.3 and 12.4, and shall have a workmanlike finish.

12.2 Surface discontinuities deeper than 5% of the specified nominal wall thickness, except as defined in 12.3 and 12.4, shall be removed by the manufacturer by machining or grinding to sound metal, and the repaired areas shall be well faired. The wall thickness at all points shall be at least 87½% of the specified nominal wall thickness, and the diameters at all points shall be within the specified limits.

12.3 Surface checks (fish scale) deeper than $\frac{1}{64}$ in. [0.4 mm] shall be removed.

12.4 Mechanical marks deeper than $\frac{1}{16}$ [1.6 mm] shall be removed.

12.5 When the removal of a surface discontinuity reduces the wall thickness below 87½% of the specified nominal wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in Section 13.

13. Repair by Welding

13.1 The fittings manufacturer may weld repair fittings, subject to the approval of the purchaser, provided the composition of the welding material is suitable for the composition of the metal being welded. Repair by welding shall not be permitted when the depth of the discontinuity exceeds 33⅓% of the nominal wall thickness or the length exceeds 25% of the nominal diameter of the fittings. Discontinuities shall be completely removed before welding. All welds shall be made by welders, welding operators, and welding procedures qualified under the provisions of ASME Section IX and heat treated after welding in accordance with Section 6.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with this specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer, unless otherwise agreed to.

14.2 Other tests, when required by agreement, shall be made from material of the lots covered in the order.

15. Rejection and Rehearing

15.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly in writing. In case of dissatisfaction with the results of the tests, the producer or supplier may make claim for a rehearing.

15.2 Fittings that develop defects in shopworking or application operations may be rejected. Upon rejection, the manufacturer shall be notified promptly in writing.

16. Certification

16.1 When requested by the purchase, the manufacturer shall provide a certificate of compliance to this specification. In addition, if requested to provide test reports, the manufacturer shall also provide the following where applicable.

16.1.1 Chemical analysis results, Section 7 (Table 1),

16.1.2 Tensile property results, Section 8 (Table 2), report the yield strength and ultimate strength in ksi [MPa] and elongation in percent,

16.1.3 Hardness acceptable in accordance with Section 9,

16.1.4 Type heat treatment, if any, Section 6,

16.1.5 Seamless or welded,

16.1.6 Starting material, specifically pipe, plate, etc.,

16.1.7 Statement regarding radiographic or ultrasonic examination, 5.3 and

16.1.8 Any supplemental testing required by the purchase order.

16.2 Letters of compliance and test reports shall state the specification number, year of issue, revision letter (if any), grade and class of the fittings.

16.3 A Material Test Report, Certificate of Inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

17. Product Marking

17.1 All fittings shall have the prescribed information stamped or otherwise suitably marked on each fitting in accordance with the Standard Marking System for Valves, Fittings, Flanges and Unions (MSS SP-25, latest edition).

17.2 The prescribed information for butt-welding fittings shall be: The manufacturer's name or trademark (see Note 2), schedule number or nominal wall thickness designation, size, grade and class (listed in Table 1) and the heat number or manufacturer's heat identification. Fittings containing welds which have been ultrasonically examined in lieu of radiography shall be marked "U" after heat identity.

NOTE 2 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component complies with this specification.

17.3 The prescribed information for threaded or socket-welding fittings shall be: The manufacturer's name or trademark (see Note 2), pressure class or schedule number and grade and class (listed in Table 1), and the heat number or the manufacturer's heat identification.

17.4 Specification number, year of issue and revision letter are not required on fittings.

17.5 *Bar Coding* — In addition to the requirements in 17.1, 17.2, 17.3, and 17.4, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 chemical analysis; grade WPC

TABLE 1
CHEMICAL REQUIREMENTS

NOTE 1 — All requirements are maximum unless otherwise indicated.
NOTE 2 — Where an ellipsis (. . .) appears in this table, there is no requirement.

Grade and Marking Symbol[A]	Composition, %									
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Nickel	Copper	Others
WPB[B,C,D]	0.30 max	0.29–1.06	0.050	0.058	0.10 min	. . .	. . .	. . .	. . .	. . .
WPC[C,D]	0.35 max	0.29–1.06	0.050	0.058	0.10 min	. . .	. . .	. . .	. . .	. . .
WP1	0.28 max	0.30–0.90	0.045	0.045	0.10–0.50	. . .	0.44–0.65	. . .	. . .	. . .
WP12 CL1, WP12 CL2	0.50–0.20	0.30–0.80	0.045	0.045	0.60 max	0.80–1.25	0.44–0.65	. . .	. . .	. . .
WP11 CL1	0.05–0.15	0.30–0.60	0.030	0.030	0.50–1.00	1.00–1.50	0.44–0.65	. . .	. . .	. . .
WP11 CL2, WP11 CL3	0.05–0.20	0.30–0.80	0.040	0.040	0.50–1.00	1.00–1.50	0.44–0.65	. . .	. . .	. . .
WP22 CL1, WP22 CL3	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	1.90–2.60	0.87–1.13	. . .	. . .	. . .
WP5	0.15 max	0.30–0.60	0.040	0.030	0.50 max	4.0–6.0	0.44–0.65	. . .	. . .	. . .
WP9	0.15 max	0.30–0.60	0.030	0.030	0.25–1.00	8.0–10.0	0.90–1.10	. . .	. . .	. . .
WPR	0.20 max	0.40–1.06	0.045	0.050	. . .	. . .	. . .	1.60–2.24	0.75–1.25	. . .
WP91	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.0–9.5	0.85–1.05	0.40 max	. . .	Vanadium 0.18–0.25 Columbium 0.06–0.10 Nitrogen 0.03–0.07 Aluminum 0.04 max

[A] When fittings are of welded construction, the grade and marking symbol shown above shall be supplemented by letter "W".
[B] Fittings made from bar or plate may have 0.35 max carbon.
[C] Fittings made from forgings may have 0.35 max carbon and 0.35 max silicon with no minimum.
[D] For each reduction of 0.01% below the specified carbon maximum, an increase of 0.06% manganese above the specified maximum will be permitted, up to a maximum of 1.35%.

TABLE 2
TENSILE REQUIREMENTS

NOTE — Where an ellipsis (. . .) appears in this table, there is no requirement.

Grade and Marking Symbol	WPB	WPC, WP11 CL2, WP12 CL2	WP1	WP11 CL1, WP22 CL1, WP5, WP9	WPR	WP11 CL3, WP22 CL3	WP91	WP12 CL1
Tensile strength, range ksi [MPa]	60–85 [415–585]	70–95 [485–655]	55–80 [380–555]	60–85 [415–585]	63–88 [435–610]	75–100 [520–690]	85–110 [590–760]	60–85 [415–585]
Yield strength, min, ksi [MPa] (0.2% offset or 0.5% extension-under-load)	35 [240]	40 [275]	30 [205]	30 [205]	46 [315]	45 [310]	60 [415]	32 [220]

	Elongation Requirements					
	Grades					
	All Grades except WPR and WP91		WPR		WP91	
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Elongation:						
Standard round specimen, or small proportional specimen, min % in 4 D	22	14	20	. . .	20	. . .
Rectangular specimen for wall thickness $\frac{5}{16}$ in. [7.94 mm] and over, and for all small sizes tested in full section; min % in 2 in. [50 mm]	30	20[A]	28	. . .	. . .	. . .
Rectangular specimen for wall thickness less than $\frac{5}{16}$ in. [7.94 mm]; min % in 2 in. [50 mm] ($\frac{1}{2}$ in. [12.7 mm] wide specimen)	[B]	[B]	[B]	. . .	. . .	. . .

[A] WPB and WPC fittings manufactured from plate shall have a minimum elongation of 17%.

[B] For each $\frac{1}{32}$ in. [0.79 mm] decrease in wall thickness below $\frac{5}{16}$ in. [7.94 mm], a deduction of 1.5% for longitudinal and 1.0% for transverse from the values shown above is permitted. The following table gives the minimum value for various wall thicknesses.

Wall Thickness		Grades			
		All Grades except WPR		WPR	
in.	[mm]	Longitudinal	Transverse	Longitudinal	Transverse
$\frac{5}{16}$ (0.312)	7.94	30.0	20.0	28.0	. . .
$\frac{9}{32}$ (0.281)	7.14	28.5	19.0	26.5	. . .
$\frac{1}{4}$ (0.250)	6.35	27.0	18.0	25.0	. . .
$\frac{7}{32}$ (0.219)	5.56	25.5	. . .	23.5	. . .
$\frac{3}{16}$ (0.188)	4.76	24.0	. . .	22.0	. . .
$\frac{5}{32}$ (0.156)	3.97	22.5	. . .	20.5	. . .
$\frac{1}{18}$ (0.125)	3.17	21.0	. . .	19.0	. . .
$\frac{3}{32}$ (0.094)	2.38	19.5	. . .	17.5	. . .
$\frac{1}{16}$ (0.062)	1.59	18.0	. . .	16.0	. . .

NOTE — This table gives the computed minimum % elongation value for each $\frac{1}{32}$ in. [0.79 mm] decrease in wall thickness. Where the wall thickness lies between two values above, the minimum elongation value is determined by the following equations:

Direction of Test	Equation
Longitudinal	$E = 48t + 15.00$
Transverse	$E = 32t + 10.00$

where:

E = elongation in 2 in. or [50 mm], %, and,

t = actual thickness of specimen, in. [mm].

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order, in which event, the supplementary requirements specified shall be made at the place of manufacture, unless otherwise agreed upon, at the purchaser's expense. The test specified shall be witnessed by the purchaser's inspector before shipment of material, if so specified in the order.

S1. Product Analysis

S1.1 A product analysis shall be made from each heat of base metal and, if of welded construction, from each lot number of welding material of the fittings offered for delivery. The analysis shall conform to the requirements specified in Section 7. (See Note 3.)

NOTE 3 — If the results of any of the tests specified in S1 or S2 do not conform to the requirements, retests may be made at the manufacturer's expense on additional fittings or representative test pieces of double the original number from the same heat or lot as defined in S1 or S2, each of which shall conform to the requirements specified.

S2. Tension Test

S2.1 One tension test shall be made on one fitting or representative test piece (see Note 4) per lot (see Note 5) of fittings. If the fittings are of welded construction, the tension specimen shall include the weld and shall be prepared so that the weld is at the mid length location of the specimen. However, in no case shall the tensile properties of the finished fittings be less than the requirements listed in Table 2. (See Note 3.)

NOTE 4 — *Representative Test Piece:* Where the test specimen for the tension test cannot be taken from a fitting due to size limitations, a representative test piece shall be obtained. The test piece shall be from the same heat and heat treated in the same batch or charge as the fittings it represents and shall have approximately the same amount of working. In addition, test pieces representing fittings manufactured from bars, plate, or forgings shall have a cross section equal to the greatest cross section of the fitting; and test pieces representing fittings manufactured from pipe shall have a wall thickness equal to those of the fitting. The test piece for fittings of welded construction shall be prepared to the same weld procedures and from the same heats of material as the fittings it represents.

NOTES 5 — A lot shall consist of all fittings of the same type, size, and wall thickness, manufactured from one heat of material (and, if welding is performed, using one lot number of electrodes or one heat of weld wire and one lot number of flux), heat treated in either a continuous or batch-type furnace controlled within a range ±25°F [±14°C] and equipped with recording pyrometers so that complete records of heat treatment are available.

S3. Liquid Penetrant Examination

S3.1 All surfaces shall be liquid penetrant examined in accordance with Practice E 165. Acceptance limits shall be specified by the purchaser. Personnel performing the examination shall be qualified in accordance with SNT-TC-1A.

S4. Magnetic-Particle Examination

S4.1 All accessible surfaces shall be magnetic particle examined in accordance with Practice E 709. Acceptance limits shall be specified by the purchaser. Personnel performing the examination shall be qualified in accordance with SNT-TC-1A.

S5. Hydrostatic Test

S5.1 A hydrostatic test shall be applied as agreed upon between the manufacturer and purchaser.

S6. Bar Stock Fittings

S6.1 Bar stock fittings shall not be permitted.

S7. Special Heat Treatment

S7.1 A special heat treatment shall be applied as agreed upon between the manufacturer and the purchaser (Section 6).

S8. Hardness Test

S8.1 If actual hardness testing of the fittings is required, the frequency and the method used shall be as agreed upon between the manufacturer and the purchaser.

S9. Special Fittings

S9.1 Partial compliance fittings of size or shape not conforming to the dimensional requirements of ANSI B16.9, B16.11, B16.28, MSS SP-79, and MSS SP-95 shall meet all other requirements of this specification. In addition to the marking required by Section 17, the grade designation symbol shall be followed by the symbol "S9".

S10. Heat Treatment of Concentric Reducers

S10.1 Concentric reducers formed by local heating of the fitting shall subsequently be annealed, normalized, or normalized and tempered.

S11. Marking Small Fittings

S11.1 For small products where the space for marking is less than 1 in. [25 mm] in any direction, test reports are mandatory and marking may be restricted to only such symbols or codes as are necessary to identify the parts with test reports.

S11.2 When the configuration or size does not permit marking directly on the fitting, the marking method shall be a matter of agreement between the manufacturer and the purchaser.

S12. Alternative Heat Treatment — Grade WP91

S12.1 Grade WP91 shall be normalized in accordance with 6.3.3 and tempered at a temperature, to be specified by the purchaser, less than 1350°F [730°C]. It shall be the purchaser's responsibility to subsequently temper the entire fitting at 1350°F [730°C] minimum. All mechanical tests shall be made on material heat treated in accordance with 6.3.3. The certification shall reference this supplementary requirement indicating the actual tempering temperature applied. The notation "S12" shall be included with the required marking of the fitting.

S13. Phosphorous and Sulphur Content

S13.1 The phosphorous and sulphur contents of the fittings shall not exceed 0.025%.

SPECIFICATION FOR HEAT-RESISTING CHROMIUM AND CHROMIUM-NICKEL STAINLESS STEEL PLATE, SHEET, AND STRIP FOR PRESSURE VESSELS

SA-240

(Identical with ASTM Specification A 240-97a, except for editorial differences in Table 1.) A99

1. Scope

1.1 This specification covers chromium, chromium-nickel, and chromium-manganese-nickel stainless and heat-resisting steel plate, sheet, and strip for pressure vessels.

1.2 Some steels covered by this specification, especially the chromium steels, because of their particular alloy content and specialized properties, may require special care in their fabrication and welding. Specific procedures are of fundamental importance, and it is presupposed that all parameters will be in accordance with approved methods capable of producing the desired properties in the finished fabrication.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 This specification and the applicable material specifications are expressed in both inch-pound and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished in inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

E 112 Test Methods for Determining Average Grain Size

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *SAE Standard:*

J 1086 Practice for Numbering Metals and Alloys (UNS)

3. General Requirements

3.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 480/A 480M.

3.1.1 Definitions,

3.1.2 General requirements for delivery,

3.1.3 Ordering information,

3.1.4 Process,

3.1.5 Special tests,

3.1.6 Heat treatment,

3.1.7 Dimensions and permissible variations,

3.1.8 Workmanship, finish and appearance,

3.1.9 Number of tests/test methods,

3.1.10 Specimen preparation,

3.1.11 Retreatment,

3.1.12 Inspection,

3.1.13 Rejection and rehearing,

3.1.14 Material test report,

3.1.15 Certification, and

3.1.16 Packaging, marking, and loading.

4. Chemical Composition

4.1 The steel shall conform to the requirements as to chemical composition specified in Table 1, and shall conform to applicable requirements specified in Specification A 480/A 480M.

5. Mechanical Properties

5.1 The material shall conform to the mechanical properties specified in Table 2.

A99 6. Grain Size for Austenitic *H* Types

6.1 The austenitic *H* Types shall conform to an average grain size of ASTM No. 7 or coarser as measured by Test Methods E 112.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS, %[A]

UNS Designation[B]	Type[C]	Carbon[D]	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements[E, F]
					Austenitic (Chromium-Nickel) (Chromium-Manganese-Nickel)							
N08367	...	0.030	2.00	0.040	0.030	1.00	20.00–22.00	23.50–25.50	6.00–7.00	0.18–0.25	0.75	...
N08800	...	0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Al 0.15–0.60 Ti 0.15–0.60
N08810	...	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Al 0.15–0.60 Ti 0.15–0.60
N08904	904L[G]	0.020	2.00	0.045	0.035	1.00	19.00–23.00	23.00–28.00	4.0–5.0	0.10	1.0–2.0	...
N08926	...	0.020	2.00	0.030	0.010	0.50	19.00–21.00	24.00–26.00	6.0–7.0	0.15–0.25	0.5–1.5	...
S20100	201	0.15	5.50–7.50	0.060	0.030	1.00	16.00–18.00	3.50–5.50	...	0.25	...	...
S20103	...	0.03	5.50–7.50	0.045	0.030	0.75	16.00–18.00	3.50–5.50	...	0.25	...	...
S20153	...	0.03	6.40–7.50	0.045	0.015	0.75	16.00–17.50	4.00–5.00	...	0.10–0.25	1.00	...
S20161	...	0.15	4.00–6.00	0.040	0.040	3.00–4.00	15.00–18.00	4.00–6.00	...	0.08–0.20	...	...
S20200	202	0.15	7.50–10.0	0.060	0.030	1.00	17.00–19.00	4.00–6.00	...	0.25	...	...
S20400	...	0.030	7.00–9.00	0.040	0.030	1.00	15.00–17.00	1.50–3.00	...	0.15–0.30	...	...
S20910	XM-19[H]	0.06	4.00–6.00	0.040	0.030	0.75	20.50–23.50	11.50–13.50	1.50–3.00	0.20–0.40	...	Cb 0.10–0.30 V 0.10–0.30
S21400	XM-31[H]	0.12	14.00–16.00	0.045	0.030	0.30–1.00	17.00–18.50	1.00	...	0.35 min	...	...
S21600	XM-17[H]	0.08	7.50–9.00	0.045	0.030	0.75	17.50–22.00	5.00–7.00	2.00–3.00	0.25–0.50	...	...
S21603	XM-18[H]	0.03	7.50–9.00	0.045	0.030	0.75	17.50–22.00	5.00–7.00	2.00–3.00	0.25–0.50	...	...
S21800	...	0.10	7.00–9.00	0.060	0.030	3.50–4.50	16.00–18.00	8.00–9.00	...	0.08–0.18	...	...
S24000	XM-29[H]	0.08	11.50–14.50	0.060	0.030	0.75	17.00–19.00	2.25–3.75	...	0.20–0.40	...	...
S30100	301	0.15	2.00	0.045	0.030	1.00	16.00–18.00	6.00–8.00	...	0.10	...	...
S30200	302	0.15	2.00	0.045	0.030	0.75	17.00–19.00	8.00–10.00	...	0.10	...	...
S30400	304	0.08	2.00	0.045	0.030	0.75	18.00–20.00	8.00–10.50	...	0.10	...	...
S30403	304L	0.030	2.00	0.045	0.030	0.75	18.00–20.00	8.00–12.00	...	0.10	...	...
S30409	304H	0.04–0.10	2.00	0.045	0.030	0.75	18.00–20.00	8.00–10.50	...	...	...	...
S30415	...	0.04–0.06	0.80	0.045	0.030	1.00–2.00	18.00–19.00	9.00–10.00	...	0.12–0.18	...	Ce 0.03–0.08
S30451	304N	0.08	2.00	0.045	0.030	0.75	18.00–20.00	8.00–10.50	...	0.10–0.16	...	...
S30452	XM-21	0.08	2.00	0.045	0.030	0.75	18.00–20.00	8.00–10.50	...	0.16–0.30	...	...
S30453	304LN	0.030	2.00	0.045	0.030	0.75	18.00–20.00	8.00–12.00	...	0.10–0.16	...	...
S30500	305	0.12	2.00	0.045	0.030	0.75	17.00–19.00	10.50–13.00	...	...	...	...
S30600	...	0.018	2.00	0.020	0.020	3.7–4.3	17.0–18.5	14.0–15.5	0.20	...	0.50	...
S30601	...	0.015	0.50–0.80	0.030	0.013	5.00–5.60	17.00–18.00	17.00–18.00	0.20	0.050	0.35	...
S30615	...	0.16–0.24	2.00	0.030	0.030	3.2–4.0	17.0–19.5	13.5–16.0	...		...	Al 0.8–1.5
S30815	...	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.00–22.00	10.00–12.00	...	0.14–0.20	...	Ce 0.03–0.08
S30908	309S	0.08	2.00	0.045	0.030	0.75	22.00–24.00	12.00–15.00	...	...	...	...
S30909	309H[G]	0.04–0.10	2.00	0.045	0.030	0.75	22.00–24.00	12.00–15.00	...	...	...	...
S30940	309Cb[G]	0.08	2.00	0.045	0.030	0.75	22.00–24.00	12.00–16.00	...	...	...	Cb 10 × C min, 1.10 max
S30941	309HCb[G]	0.04–0.10	2.00	0.045	0.030	0.75	22.00–24.00	12.00–16.00	...	...	...	Cb 10 × C min, 1.10 max
S31008	310S	0.08	2.00	0.045	0.030	1.50	24.00–26.00	19.00–22.00	...	...	...	...
S31009	310H[G]	0.04–0.10	2.00	0.045	0.030	0.75	24.00–26.00	19.00–22.00	...	...	...	...
S31040	310Cb[G]	0.08	2.00	0.045	0.030	1.50	24.00–26.00	19.00–22.00	...	...	...	Cb 10 × C min, 1.10 max
S31041	310HCb[G]	0.04–0.10	2.00	0.045	0.030	0.75	24.00–26.00	19.00–22.00	...	...	...	Cb 10 × C min, 1.10 max

TABLE 1 (CONT'D)
CHEMICAL COMPOSITION REQUIREMENTS, %[A]

UNS Designation[B]	Type[C]	Carbon[D]	Manganese	Phos-phorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements[E, F]
Austenitic (Chromium-Nickel) (Chromium-Manganese-Nickel)												
S31050	310MoLN[G]	0.030	2.00	0.030	0.010	0.50	24.00–26.00	21.00–23.00	2.00–3.00	0.10–0.16	...	...
S31254	...	0.020	1.00	0.030	0.010	0.80	19.50–20.50	17.50–18.50	6.00–6.50	0.18–0.22	0.50–1.00	...
S31266	...	0.030	2.00–4.00	0.035	0.020	1.00	23.00–25.00	21.00–24.00	5.00–7.00	0.35–0.60	0.50–3.00	W 1.00–3.00
S31600	316	0.08	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	2.00–3.00	0.10	...	...
S31603	316L	0.030	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	2.00–3.00	0.10	...	...
S31609	316H	0.04–0.10	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	2.00–3.00	...	...	...
S31635	316Ti[G]	0.08	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	2.0–3.0	0.10	...	Ti 5 × (C + N) min, 0.70 max
S31640	316Cb[G]	0.08	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	2.0–3.0	0.10	...	Cb 10 × C min, 1.10 max
S31651	316N	0.08	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	2.00–3.00	0.10–0.16	...	...
S31653	316LN	0.030	2.00	0.045	0.030	0.75	16.00–18.00	10.00–14.00	2.00–3.00	0.10–0.16	...	...
S31700	317	0.08	2.00	0.045	0.030	0.75	18.00–20.00	11.00–15.00	3.00–4.00	0.10	...	...
S31703	317L	0.030	2.00	0.045	0.030	0.75	18.00–20.00	11.00–15.00	3.00–4.00	0.10	...	...
S31725	...	0.030	2.00	0.045	0.030	0.75	18.00–20.00	13.50–17.50	4.0–5.0	0.20	...	...
S31726	...	0.030	2.00	0.045	0.030	0.75	17.00–20.00	13.50–17.50	4.0–5.0	0.10–0.20	...	...
S31753	317LN[G]	0.030	2.00	0.045	0.030	0.75	18.00–20.00	11.00–15.00	3.00–4.00	0.10–0.22	...	...
S32050	...	0.030	1.50	0.035	0.020	1.00	22.00–24.00	20.00–22.00	6.00–6.80	0.24–0.34	0.40	...
S32100	321	0.08	2.00	0.045	0.030	0.75	17.00–19.00	9.00–12.00	...	0.10	...	Ti 5 × (C + N) min, 0.70 max
S32109	321H	0.04–0.10	2.00	0.045	0.030	0.75	17.00–19.00	9.00–12.00	...	...	...	Ti 4 × (C + N) min, 0.70 max
S32615	...	0.07	2.00	0.045	0.030	4.8–6.0	16.5–19.5	19.0–22.0	0.30–1.5	...	1.5–2.5	...
S32654	...	0.020	2.00–4.00	0.030	0.005	0.50	24.00–25.00	21.00–23.00	7.00–8.00	0.45–0.55	0.30–0.60	...
S33228	...	0.04–0.08	1.00	0.020	0.015	0.030	26.0–28.0	31.0–33.0	...	...	...	Ce 0.05–0.10 Cb 0.6–1.0 Al 0.025
S34565	...	0.030	5.00–7.00	0.030	0.010	1.00	23.00–25.00	16.00–18.00	4.00–5.00	0.40–0.60	...	Cb 0.10
S34700	347	0.08	2.00	0.045	0.030	0.75	17.00–19.00	9.00–13.00	...	...	...	Cb 10 × C min, 1.00 max
S34709	347H	0.04–0.10	2.00	0.045	0.030	0.75	17.00–19.00	9.00–13.00	...	...	...	Cb 8 × C min, 1.00 max
S34800	348	0.08	2.00	0.045	0.030	0.75	17.00–19.00	9.00–13.00	...	...	...	Cb + Ta 10 × C min, 1.00 max Ta 0.10 max Co 0.20
S34809	348H	0.04–0.10	2.00	0.045	0.030	0.75	17.00–19.00	9.00–13.00	...	...	...	Cb + Ta 8 × C min, 1.00 max Ta 0.10 max Co 0.20
S35315	...	0.04–0.08	2.00	0.040	0.030	1.20–2.00	24.00–26.00	34.00–36.00	...	0.12–0.18	...	Ce 0.03–0.08
S38100	XM-15[H]	0.08	2.00	0.030	0.030	1.50–2.50	17.00–19.00	17.50–18.50	...	...	...	...

TABLE 1 (CONT'D)
CHEMICAL COMPOSITION REQUIREMENTS, %[A]

UNS Designation[B]	Type[C]	Carbon[D]	Manganese	Phos-phorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements[E, F]
Duplex (Austenitic-Ferritic)												
S31200	...	0.030	2.00	0.045	0.030	1.00	24.0–26.0	5.5–6.5	1.2–2.0	0.14–0.20	...	...
S31260	...	0.03	1.00	0.030	0.030	0.75	24.0–26.0	5.50–7.50	2.50–3.50	0.10–0.30	0.20–0.80	W 0.10–0.50
S31803	...	0.030	2.00	0.030	0.020	1.00	21.0–23.0	4.50–6.50	2.50–3.50	0.08–0.20	...	...
S32001	...	0.030	4.0–6.0	0.040	0.030	1.00	19.5–21.5	1.00–3.00	0.60	0.05–0.17	1.00	...
S32205	...	0.030	2.00	0.030	0.020	1.00	22.0–23.0	4.50–6.50	3.00–3.50	0.14–0.20	...	...
S32304	...	0.030	2.50	0.040	0.030	1.00	21.5–24.5	3.00–5.50	0.05–0.60	0.05–0.20	0.05–0.60	...
S32520	...	0.030	1.50	0.035	0.020	0.80	24.00–26.00	5.50–8.00	3.00–5.00	0.20–0.35	0.50–3.00	...
S32550	...	0.04	1.5	0.040	0.030	1.0	24.0–27.0	4.5–6.5	2.9–3.9	0.10–0.25	1.5–2.5	...
S32750	...	0.030	1.20	0.035	0.020	0.80	24.0–26.0	6.00–8.00	3.00–5.00	0.24–0.32	0.50	...
S32760	...	0.030	1.00	0.030	0.010	1.00	24.00–26.00	6.00–8.00	3.00–4.00	0.20–0.30	0.50–1.00	W 050–1.00 Cr + 3.3 Mo + 16 N = 40 min
S32900	329	0.08	1.00	0.040	0.030	0.75	23.00–28.00	2.50–5.00	1.0–2.0	...	...	...
S32950	...	0.03	2.00	0.035	0.010	0.60	26.00–29.00	3.50–5.20	1.00–2.50	0.15–0.35	...	...
Ferritic or Martensitic (Chromium)												
S32803	...	0.015	0.50	0.020	0.0035	0.55	28.00–29.00	3.0–4.0	1.8–2.5	0.020 (C + N) 0.030 max	...	Cb 0.15–0.50 12 (C + N) min
S40500	405	0.08	1.00	0.040	0.030	1.00	11.50–14.50	0.60	...	...	...	Al 0.10–0.30
S40900[I]	409[I]											
S40910	...	0.030	1.00	0.040	0.010	1.00	10.5–11.7	0.50	...	0.030	...	Ti 6 × (C + N) min; 0.50 max
S40920	...	0.030	1.00	0.040	0.010	1.00	10.5–11.7	0.50	...	0.030	...	Ti 8 × (C + N) min; 0.15–0.50
S40930	...	0.030	1.00	0.040	0.010	1.00	10.5–11.7	0.50	...	0.030	...	(Cb + Ti) 0.08 + 8 (C + N) min; 0.75 max; Ti 0.05 min
S40945	...	0.030	1.00	0.040	0.030	1.00	10.50–11.75	0.50	...	0.030	...	Cb 0.18–0.40 Ti 0.05–0.20
S40975	...	0.030	1.00	0.040	0.030	1.00	10.50–11.75	0.50–1.00	...	0.030	...	Ti 6 (C + N) min and 0.75 max
S41000	410	0.15	1.00	0.040	0.030	1.00	11.50–13.50	0.75	...	...	...	...
S41003	...	0.03	1.50	0.040	0.030	1.00	10.50–12.50	1.50	...	...	...	N 0.030 max
S41008	410S	0.08	1.00	0.040	0.030	1.00	11.50–13.50	0.60	...	...	...	...
S41045	...	0.030	1.00	0.040	0.030	1.00	12.00–13.00	0.50	...	0.030	...	Cb 9 (C + N) min, 0.60 max
S41050	...	0.040	1.00	0.045	0.030	1.00	10.50–12.50	0.60–1.10	...	0.10	...	...
S41500[E]	...	0.05	0.5–1.0	0.030	0.030	0.60	11.5–14.0	3.5–5.5	0.5–1.0	...	...	...
S42900	429[G]	0.12	1.00	0.040	0.030	1.00	14.00–16.00	...	...	...	...	...
S43000	430	0.12	1.00	0.040	0.030	1.00	16.00–18.00	0.75	...	...	...	...
S43035	439	0.07	1.00	0.040	0.030	1.00	17.00–19.00	0.050	...	0.04	...	Ti 0.20 + 4 (C + N) min; 1.10 max Al 0.15 max

TABLE 1 (CONT'D)
CHEMICAL COMPOSITION REQUIREMENTS, %[A]

UNS Designation[B]	Type[C]	Carbon[D]	Manganese	Phos-phorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements[E, F]
						Ferritic or Martensitic (Chromium)						
S43400	...	0.12	1.00	0.040	0.030	1.00	16.00–18.00	...	0.75–1.25	...	...	...
S43600	...	0.12	1.00	0.040	0.030	1.00	16.00–18.00	...	0.75–1.25	...	...	Cb 5 × C min; 0.80 max
S43932	...	0.030	1.00	0.040	0.030	1.00	17.0–19.0	0.50	...	0.030	...	Ti + Cb 0.20 + 4 (C + N) min; 0.75 max Al 0.15 max
S44400	444	0.025	1.00	0.040	0.030	1.00	17.5–19.5	1.00	1.75–2.50	0.035	...	Ti + Cb 0.20 + 4 (C + N) min; 0.80 max
S44500	...	0.020	1.00	0.040	0.012	1.00	19.00–21.00	0.60	...	0.03	0.30–0.60	Cb 10 (C + N) – 0.80
S44626	XM-33[H]	0.06	0.75	0.040	0.020	0.75	25.00–27.00	0.50	0.75–1.50	0.04	0.20	Ti 0.20–1.00 7 (C + N) min
S44627	XM-27[H]	0.010[G]	0.40	0.020	0.020	0.40	25.00–27.50	0.50	0.75–1.50	0.015[E]	0.20	Cb 0.05–0.20 Ni + Cu 0.50 max
S44635	...	0.025	1.00	0.040	0.030	0.75	24.5–26.0	3.5–4.5	3.5–4.5	0.035	...	Ti + Cb 0.20 + 4 (C + N) min; 0.80 max
S44660	...	0.030	1.00	0.040	0.030	1.00	25.0–28.0	1.0–3.50	3.00–4.00	0.040	...	Ti + Cb = 0.20 – 1.00 and 6 (C + N) min
S44700	...	0.010	0.30	0.025	0.020	0.20	28.0–30.0	0.15	3.5–4.2	0.020	0.15	(C + N) 0.025 max
S44735	...	0.030	1.00	0.040	0.030	1.00	28.00–30.00	1.00	3.60–4.20	0.045	...	Ti + Cb = 0.20–1.00 and 6 (C + N) min
S44800	...	0.010	0.30	0.025	0.020	0.20	28.0–30.0	2.0–2.5	3.5–4.2	0.020	0.15	(C + N) 0.025 max
S46800	...	0.030	1.00	0.040	0.030	1.00	18.00–20.00	0.50	...	...	...	Ti 0.07–0.30 Cb 0.10–0.60 N 0.030 max Ti + Cb = 0.20 + 4 (C + N) min; 0.80 max

[A] Maximum, unless range or minimum is indicated.
[B] Designation established in accordance with Practice E 527 and SAE J 1086.
[C] Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).
[D] Carbon analysis shall be reported to nearest 0.01% except for the low-carbon types, which shall be reported to nearest 0.001%.
[E] The terms Columbium (Cb) and Niobium (Nb) both relate to the same element.
[F] When two minimums or two maximums are listed for a single type, as in the case of both a value from a formula and an absolute value, the higher minimum or lower maximum shall apply.
[G] Common name, not a trademark, widely used, not associated with any one producer.
[H] Naming system developed and applied by ASTM.
[I] S40900 (Type 409) has been replaced by S40910, S40920, and S40930. Unless otherwise specified in the ordering information, an order specifying S40900 or Type 409 shall be satisfied by any one of S40910, S40920, or S40930 at the option of the seller. Material meeting the requirements of S40910, S40920, or S40930, may at the option of the manufacturer be certified as S40900.

TABLE 2
MECHANICAL TEST REQUIREMENTS

A99

UNS Designation	Type[A]	Tensile Strength, min ksi	Tensile Strength, min MPa	Yield Strength[B] min ksi	Yield Strength[B] min MPa	Elongation in 2 in. or 50 mm, min, %	Hardness, max[C] Brinell	Hardness, max[C] Rockwell B	Cold Bend°
Austenitic (Chromium-Nickel) (Chromium-Manganese-Nickel)									
N08367									
Sheet and Strip		100	690	45	310	30.0	...	100	not required
Plate		95	655	45	310	30.0	241	...	not required
N08800	...	75	520	30[D]	205[D]	30.0[E]	...	...	not required
N08810	...	65	450	25[D]	170[D]	30.0	...	...	not required
N08904	904L[F]	71	490	31	220	35.0	...	90	not required
N08926	...	94	650	43	295	35.0	...	...	not required
S20100	201-1[G]	75	515	38	260	40.0	...	95	...
S20100	201-2[G]	95	655	45	310	40.0	217	100	...
S20103	201L[F]	95	655	38	260	40.0	217	95	not required
S20153	201LN[F]	95	655	45	310	45.0	241	100	not required
S20161	...	125	860	50	345	40.0	255	25[H]	not required
S20200	202	90	620	38	260	40.0	241	...	...
S20400	...	95	655	48	330	35.0	241	100	not required
S30100	301	75	515	30	205	40.0	217	95	not required
S30200	302	75	515	30	205	40.0	201	92	not required
S30400	304	75	515	30	205	40.0	201	92	not required
S30403	304L	70	485	25	170	40.0	201	92	not required
S30409	304H	75	515	30	205	40.0	201	92	not required
S30415	...	87	600	42	290	40.0	217	95	not required
S30451	304N	80	550	35	240	30.0	201	92	not required
S30453	304LN	75	515	30	205	40.0	201	92	not required
S30500	305	75	515	30	205	40.0	183	88	not required
S30600	...	78	540	35	240	40.0	...	...	...
S30601	...	78	540	37	255	30.0	...	...	not required
S30615	...	90	620	40	275	35.0	217	95	not required
S30815	...	87	600	45	310	40.0	217	95	...
S30908	309S	75	515	30	205	40.0	217	95	not required
S30909	309H[F]	75	515	30	205	40.0	217	95	not required
S30940	309Cb[F]	75	515	30	205	40.0	217	95	not required
S30941	309HCb[F]	75	515	30	205	40.0	217	95	not required
S31008	310S	75	515	30	205	40.0	217	95	not required
S31009	310H[F]	75	515	30	205	40.0	217	95	not required
S31040	310Cb[F]	75	515	30	205	40.0	217	95	not required
S31041	310HCb[F]	75	515	30	205	40.0	217	95	not required
S31254	...	94	650	44	300	35.0	223	96	not required
S31266	...	109	750	61	420	35.0	...	...	not required
S31600	316	75	515	30	205	40.0	217	95	not required
S31603	316L	70	485	25	170	40.0	217	95	not required
S31653	316LN	75	515	30	205	40.0	217	95	not required
S31609	316H	75	515	30	205	40.0	217	95	not required
S31635	316Ti[F]	75	515	30	205	40.0	217	95	not required
S31640	316Cb[F]	75	515	30	205	30.0	217	95	not required
S31651	316N	80	550	35	240	35.0	217	95	not required
S31700	317	75	515	30	205	35.0	217	95	not required
S31725	...	75	515	30	205	40.0	217	95	not required
S31726	...	80	550	35	240	40.0	223	96	not required
S31703	317L	75	515	30	205	40.0	217	95	not required
S31753	317LN	80	550	35	240	40.0	217	95	not required
S32050	...	98	675	48	330	40.0	250	...	not required
S32100	321	75	515	30	205	40.0	217	95	not required
S32109	321H	75	515	30	205	40.0	217	95	not required
S32615[I]	...	80	550	32	220	25	...	...	not required
S32654	...	109	750	62	430	40.0	250	...	not required
S33228	...	73	500	27	185	30.0	217	95	not required
S34565	...	115	795	60	415	35.0	241	100	not required
S34700	347	75	515	30	205	40.0	201	92	not required
S34709	347H	75	515	30	205	40.0	201	92	not required
S34800	348	75	515	30	205	40.0	201	92	not required
S34809	348H	75	515	30	205	40.0	201	92	not required
S35315	...	94	650	39	270	40.0	217	95	not required

A99

TABLE 2 (CONT'D)
MECHANICAL TEST REQUIREMENTS

UNS Designation	Type[A]	Tensile Strength, min ksi	Tensile Strength, min MPa	Yield Strength[B] min ksi	Yield Strength[B] min MPa	Elongation in 2 in. or 50 mm, min, %	Hardness, max[C] Brinell	Hardness, max[C] Rockwell B	Cold Bend°
Austenitic (Chromium-Nickel) (Chromium-Manganese-Nickel)									
S38100	XM-15[J]	75	515	30	205	40.0	217	95	not required
S30452	XM-21[J]								
Sheet and Strip		90	620	50	345	30.0	241	100	not required
Plate		85	585	40	275	30.0	241	100	not required
S31050	310MoLN[F]	80	550	35	240	30	217	95	not required
S21600	XM-17[H]								
Sheet and Strip		100	690	60	415	40.0	241	100	not required
Plate		90	620	50	345	40.0	241	100	not required
S21603	XM-18[J]								
Sheet and Strip		100	690	60	415	40.0	241	100	not required
Plate		90	620	50	345	40.0	241	100	not required
S20910	XM-19[J]								
Sheet and Strip		105	725	60	415	30.0	241	100	not required
Plate		100	690	55	380	35.0	241	100	not required
S24000	XM-29[J]								
Sheet and Strip		100	690	60	415	40.0	241	100	not required
Plate		100	690	55	380	40.0	241	100	not required
S21400	XM-31[J]								
Sheet		125	860	70	485	40.0	...	...	not required
Strip		105	725	55	380	40.0	...	...	not required
S21800	...	95	655	50	345	35.0	241	100	not required
Duplex (Austenitic-Ferritic)									
S31200	...	100	690	65	450	25.0	293	31[H]	not required
S31260	...	100	690	70	485	20.0	290	...	...
S31803	...	90	620	65	450	25.0	293	31[H]	not required
S32001	...	90	620	65	450	25.0	...	25[D]	not required
S32205	...	90	620	65	450	25.0	293	31[H]	not required
S32304	...	87	600	58	400	25.0	290	32[H]	not required
S32520	...	112	770	80	550	25.0	310	...	not required
S32550	...	110	760	80	550	15.0	302	32[H]	not required
S32750	...	116	795	80	550	15.0	310	32[H]	not required
S32760	...	108	750	80	550	25.0	270	...	not required
S32900	329	90	620	70	485	15.0	269	28[H]	not required
S32950[K]	...	100	690	70	485	15.0	293	32[H]	not required
Ferritic or Martensitic (Chromium)									
S32803	...	87	600	72	500	16.0	241	100	not required
S40500	405	60	415	25	170	20.0	179	88	180
S40900[L]	409[L]								
S40910	...	55	380	25	170	20.0	179	88	180
S40920	...	55	380	25	170	20.0	179	88	180
S40930	...	55	380	25	170	20.0	179	88	180
S40945	...	55	380	30	205	22.0	...	80	180
S40975	...	60	415	40	275	20.0	197	92	180
S41000	410	65	450	30	205	20.0	217	96	180
S41003	...	66	455	40	275	18.0	223	20[H]	not required
S41008	410S	60	415	30	205	22.0[M]	183	89	180
S41045	...	55	380	30	205	22.0	...	80	180
S41050	...	60	415	30	205	22.0	183	89	180
S41500	...	115	795	90	620	15.0	302	32[H]	not required
S42900	429[F]	65	450	30	205	22.0[M]	183	89	180
S43000	430	65	450	30	205	22.0[M]	183	89	180
S43035	439	60	415	30	205	22.0	183	89	180
S43400	...	65	450	35	240	22.0	...	89	180
S43600	...	65	450	35	240	22.0	...	89	180
S43932	...	60	415	30	205	22.0	183	89	180
S44400	...	60	415	40	275	20.0	217	96	180
S44500	...	62	427	30	205	22	...	83	180
S44626	XM-33[J]	68	470	45	310	20.0	217	96	180
S44627	XM-27[J]	65	450	40	275	22.0	187	90	180
S44635	...	90	620	75	515	20.0	269	28[F]	180

TABLE 2 (CONT'D)
MECHANICAL TEST REQUIREMENTS

A99

UNS Designation	Type[A]	Tensile Strength, min ksi	Tensile Strength, min MPa	Yield Strength[B] min ksi	Yield Strength[B] min MPa	Elongation in 2 in. or 50 mm, min, %	Hardness, max[C] Brinell	Hardness, max[C] Rockwell B	Cold Bend[D]
Ferritic or Martensitic (Chromium)									
S44660	...	85	585	65	450	18.0	241	100	180
S44700	...	80	550	60	415	20.0	223	20[F]	180
S44735	...	80	550	60	415	18.0	255	25[F]	180
S44800	...	80	550	60	415	20.0	223	20[F]	180
S46800	...	60	415	30	205	22	...	90	180

[A] Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).
[B] Yield strength shall be determined by the offset method at 0.2% in accordance with Test Methods and Definitions A 370. Unless otherwise specified (see Specification A 480/A 480M, paragraph 4.1.11 in Ordering Information), an alternative method of determining yield strength may be based on total extension under load of 0.5%.
[C] Either Brinell or Rockwell B Hardness is permissible.
[D] Yield strength requirements shall not apply to material under 0.020 in. (0.50 mm) in thickness.
[E] Not applicable for thickness under 0.010 in. (0.25 mm).
[F] Common name, not a trademark, widely used, not associated with any one producer.
[G] Type 201 is generally produced with a chemical composition balanced for rich side (Type 201-1) or lean side (Type 201-2) austenite stability depending on the properties required for specific applications.
[H] Rockwell C scale.
[I] For S32615, the grain size as determined in accordance with the Test Methods E 112, Comparison Method, Plate II, shall be No. 3 or finer.
[J] Naming system developed and applied by ASTM.
[K] Prior to Specification A 240–89b, the tensile value for S32950 was 90 ksi.
[L] S40900 (Type 409) has been replaced by S40910, S40920, and S40930. Unless otherwise specified in the ordering information, an order specifying S40900 or Type 409 shall be satisfied by any one of S40910, S40920, or S40930 at the option of the seller. Material meeting the requirements of S40910, S40920, or S40930, may at the option of the manufacturer be certified as S40900.
[M] Material 0.050 in (1.27 mm) and under in thickness shall have a minimum elongation of 20.0%.

SPECIFICATION FOR WELDED AUSTENITIC STEEL BOILER, SUPERHEATER, HEAT-EXCHANGER, AND CONDENSER TUBES

SA-249/SA-249M

(Identical with ASTM Specification A 249/A 249M-96a except for the deletion of S5, which addresses unstraightened tubes, and clarified heat treatment requirements in 6.2.) 98

1. Scope

1.1 This specification covers nominal-wall-thickness welded tubes made from the austenitic steels listed in Table 1, with various grades intended for such use as boiler, superheater, heat exchanger, or condenser tubes.

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H are modifications of grades TP304, TP309S, TP309Cb, TP310S, TP310Cb, TP316, TP321, TP347, and TP348, and are intended for high-temperature service such as for superheaters and reheaters.

1.3 The tubing sizes and thickness usually furnished to this specification are $\frac{1}{8}$ in. [3.2 mm] in inside diameter to 5 in. [127 mm] in outside diameter and 0.015 to 0.320 in. [0.4 to 8.1 mm], inclusive, in wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.4 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.5 Optional supplementary requirements are provided and, when one or more of these are desired, each shall be so stated in the order.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

1.7 The following safety hazards caveat pertains only to the test method described in the Supplementary Requirements of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific warning statement is given in Supplementary Requirement S7, Note 5. 98

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet and Strip

E 112 Test Methods for Determining Average Grain Size
E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing
E 527 Practice for Numbering Metals and Alloys (UNS)

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, meters, or number of lengths),

4.1.2 Name of material (welded tubes),

4.1.3 Grade (Table 1),

4.1.4 Size (outside diameter and nominal wall thickness),

4.1.5 Length (specific or random),

4.1.6 Optional requirements (13.6),

4.1.7 Test report required (see Certification Section of Specification A 450/A 450M),

4.1.8 Specification designation, and

4.1.9 Special requirements and any supplementary requirements selected.

5. Manufacture

5.1 The tubes shall be made from flat-rolled steel by an automatic welding process with no addition of filler metal.

5.2 Subsequent to welding and prior to final heat treatment, the tubes shall be cold worked either in both weld and base metal or in weld metal only. The method of cold working may be specified by the purchaser. When cold drawn, the purchaser may specify the minimum amount of reduction in cross-sectional area or wall thickness, or both.

6. Heat Treatment

6.1 All material shall be furnished in the heat-treated condition. The heat-treatment procedure, except for "H" grades, S30815, S31254, S32654, N08367, N08904, and N08926 shall consist of heating the material to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means. 98

6.2 All H grades, S33228, and S30815 shall be furnished in the heat-treated condition. For these grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. The minimum solution-treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000°F [1100°C] and for Grades TP304H and TP316H, 1900°F [1040°C]. The minimum solution temperature for S33228 shall be 2050°F [1120°C]. The minimum solution-treating temperature for S30815 shall be 1920°F [1050°C]. The minimum solution treating temperature for TP309H, TP309HCb, TP310H, TP310HCb, shall be 1900°F [1040°C].

6.3 S31254 and S32654 shall be heat-treated to a minimum temperature of 2100°F [1150°C] followed by quenching in water or rapidly cooling by other means.

6.4 S24565 shall be heat-treated in the range 2050°F [1120°C] to 2140°F [1170°C] followed by quenching in water or rapidly cooling by other means.

6.5 N08904 shall be heat treated to a minimum temperature of 2000°F (1100°C) followed by quenching in water or rapidly cooling by other means. 98

6.6 N08926 shall be heat-treated to a minimum temperature of 2000°F [1100°C] followed by quenching in water or rapidly cooling by other means. 98

6.7 A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial 98

high temperature solution anneal (see Supplementary Requirement S4).

98 **6.8** UNS N08367 should be solution annealed from 2025°F minimum followed by rapid quenching.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Product Analysis

8.1 An analysis of either one length of flat-rolled stock or one tube shall be made on each heat. The chemical composition thus determined shall conform to the requirements specified in Section 7.

8.2 A product analysis tolerance of Table A1.1 in Specification A 480/A 480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04% or less.

8.3 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 1) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of the specification shall be rejected.

NOTE 1 — For flattening and flange requirements, the term lot applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

NOTE 2 – For tension and hardness test requirements, the term lot applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, annealed in the same furnace at the same temperature, time at heat, and furnace speed.

9. Tensile Requirements

9.1 The material shall conform to the tensile properties prescribed in Table 3.

10. Hardness Requirements

10.1 The tubes shall have a Rockwell hardness number not exceeding the values specified in Table 3.

11. Reverse-Bend Test Requirement

11.1 A section 4 in. [100 mm] in length shall be split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a diameter four times the wall thickness, with the mandrel parallel to the weld and on the outside of the tube. The weld shall be at the point of maximum bend. There shall be no evidence of cracks or lack of penetration in the weld, or of overlaps resulting from the reduction in thickness of the weld areas by cold working.

NOTE 3 — The reverse bend test is not applicable when the specified wall is 10% or more of the specified outside diameter, or the wall thickness is 0.134 in. [3.4 mm] or greater, or the outside diameter size is less than 0.375 in. [9.5 mm]. Under these conditions the reverse flattening test of Specification A 450/A 450 M shall apply.

12. Grain Size Requirement

12.1 The grain size of Grades TP309H, TP309HCb, TP310H and TP310HCb, as determined in accordance with Test Methods E 112, shall be No. 6 or coarser.

12.2 The grain size of Grade TP321H, as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

13. Mechanical Tests and Grain Size Determinations Required

13.1 *Tension Test* — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 2).

13.2 *Flattening Test* — One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot (Note 1).

13.3 *Flange Test* — One flange test shall be made on specimens from each end of one finished tube, not

the one used for the flattening test, from each lot (Note 1).

13.4 *Reverse-Bend Test* — One reverse-bend test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

13.5 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 2).

13.6 *Hydrostatic or Nondestructive Electric Test* — Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

13.7 *Grain Size* — Grain size determinations on grades TP309H, TP309HCb, TP310H and TP310HCb shall be made on the same number of tubes as prescribed for the flattening test.

14. Permissible Variations in Dimensions

14.1 Dimensional tolerances other than wall thickness tolerances shall be in accordance with Specification A 450/A 450M. Wall thickness tolerances shall be ±10% of nominal wall for all tubing sizes.

15. Workmanship, Finish, and Appearance

15.1 Finished tubes shall have smooth ends free of burrs and shall not deviate from straightness by more than 0.030 in. [0.8 mm] in 3 ft [900 mm] of length.

16. Surface Condition

16.1 The tubes, after final heat treatment, shall be chemically descaled or pickled free of scale. When bright annealing is used, pickling or chemical descaling is not necessary.

17. Forming Operations

17.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. All tubes, when properly manipulated, shall be able to stand expanding and beading without showing cracks and flaws, and also shall stand all forging, welding, and bending operations necessary for application without developing defects.

18. Product Marking

18.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking for Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H shall also include the heat number and the heat-treatment lot identification.

19. Keywords

19.1 austenitic stainless steel; boiler tubes; condenser tube; heat exchanger tube; high temperature applications; steel tube; superheater tubes; temperature service applications, high; welded steel tube

TABLE 1
CHEMICAL REQUIREMENTS %

Grade	Composition, %																					
	TP 201	TP 202	TP 304	TP 304H	TP 304L	TP 304N	TP 304LN	TP 305	TP 309Cb	TP 309H	TP 309HCb	TP 309S	TP 310Cb	TP 310H	TP 310HCb	TP 310S	TP 316	TP 316H	TP 316L	TP 316N	TP 316LN	TP 317
UNS Designation[A]	S20100	S20200	S30400	S30409	S30403	S30451	S30453	S30500	S30940	S30909	S30941	S30908	S31040	S31009	S31041	S31008	S31600	S31609	S31603	S31651	S31653	S31700
Carbon	0.15 max	0.15 max	0.08 max	0.04–0.10	0.035 max[B]	0.08 max	0.035 max[B]	0.12 max	0.08 max	0.04–0.10	0.04–0.10	0.08 max	0.08 max	0.04–0.10	0.04–0.10	0.08 max	0.08 max	0.04–0.10	0.035 max[B]	0.08 max	0.035 max[B]	0.08 max
Manganese, max[H]	5.50–7.50	7.50–10.0	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Phosphorus, max	0.060	0.060	0.040	0.040	0.040	0.040	0.040	0.045	0.045	0.040	0.045	0.045	0.045	0.040	0.045	0.045	0.040	0.040	0.040	0.040	0.040	0.04
Sulfur, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.03
Silicon, max	1.00	1.00	0.75	0.75	0.75	0.75	0.75	1.00	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Nickel	3.50–5.50	4.00–6.00	8.00–11.0	8.00–11.0	8.00–13.0	8.00–11.0	8.00–13.0	10.0–13.0	12.0–16.0	12.0–15.0	12.0–16.0	12.0–15.0	19.0–22.0	19.0–22.0	19.0–22.0	19.0–22.0	10.0–14.0	10.0–14.0	10.0–15.0	10.0–14.0	10.0–15.0	11.0–14.0
Chromium	16.0–18.0	17.0–19.0	18.0–20.0	18.0–20.0	18.0–20.0	18.0–20.0	18.0–20.0	17.0–19.0	22.0–24.0	22.0–24.0	22.0–24.0	24.0–26.0	24.0–26.0	24.0–26.0	24.0–26.0	24.0–26.0	16.0–18.0	16.0–18.0	16.0–18.0	16.0–18.0	16.0–18.0	18.00–20.0
Molybdenum	...	...	...	...	...	...	...	...	0.75 max	...	0.75 max	0.75 max	0.75 max	...	0.75 max	0.75 max	2.00–3.00	2.00–3.00	2.00–3.00	2.00–3.00	2.00–3.00	3.00–4.00
Titanium		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Columbium + tantalum	...	...	...	...	...	...	...	...	10 × C min, 1.10 max	...	10 × C min, 1.10 max	...	10 × C min, 1.10 max	...	10 × C min, 1.10 max	...	...	...	...	...	...	...
Tantalum, max	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nitrogen[G]	0.25 max	0.25 max	...	...	...	0.10–0.16	0.10–0.16	...	...	...	...	...	...	...	...	...	...	...	...	0.10–0.16	0.10–0.16	...
Vanadium	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Others	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

TABLE 1
CHEMICAL REQUIREMENTS % (CONT'D)

Grade	Composition, %																						
	TP 317L	TP 321	TP 321H	TP 347	TP 347H	TP 348	TP 348H	XM-15	TP XM-19	TP XM-29	...	...	...	...	...	...	...	...	...	...	...	...	...
UNS Designation	S31703	S32100	S32109	S34700	S34709	S34800	S34809	S38100	S20910	S24000	S30615	S31050	S31254	S30815	S31725	S31726	S24565	S33228	S30415	S32654	N08367	N08926	N08904
Carbon	0.035 max	0.08 max	0.04–0.10	0.08 max	0.04–0.10	0.08 max	0.04–0.10	0.08 max	0.06 max	0.08 max	0.16–0.24	0.025 max	0.02 max	0.05–0.10	0.03 max	0.03 max	0.03 max	0.04–0.08	0.04–0.06	0.020 max	0.030 max	0.020 max	0.020 max
Manganese, max[H]	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	4.00–6.00	11.5–14.5	2.00	2.00	1.00	0.80	2.00	2.00	5.0–7.0	1.0	0.80	2.00–4.00	2.00 max	2.00	2.00
Phosphorus, max	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.03	0.020	0.03	0.04	0.045	0.045	0.030	0.020	0.045	0.030	0.040 max	0.03	0.045
Sulfur, max	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.015	0.01	0.03	0.03	0.03	0.010	0.015	0.030	0.005	0.030	0.01	0.035
Silicon, max[H]	0.75	0.75	0.75	0.75	0.75	0.75	0.75	1.50–2.50	1.00	1.00	3.2–4.0	0.4	0.80	1.40–2.00	0.75	0.75	1.00	0.30	1.00–2.00	0.50	1.00	0.5	1.00
Nickel	11.0–15.0	9.00–13.0	9.00–13.0	9.00–13.0	9.00–13.0	9.00–13.0	9.00–13.0	17.5–18.5	11.5–13.5	2.25–3.75	13.5–16.0	20.5–23.5	17.5–18.5	10.0–12.0	13.5–17.5	13.5–17.5	16.0–18.0	31.0–33.0	9.00–10.00	21.0–23.0	23.50–25.50	24.00–26.00	23.0–28.0
Chromium	18.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–19.0	20.5–23.5	17.0–19.0	17.0–19.5	24.0–26.0	19.5–20.5	20.0–22.0	18.0–20.0	17.0–20.0	23.0–25.0	26.0–28.0	18.0–19.0	24.0–25.0	20.00–22.00	19.00–21.00	19.0–23.0
Molybdenum	3.00–4.00	...	...	...	...	...	...	...	1.50–3.00	...	...	1.6–2.6	6.00–6.50	...	4.0–5.0	4.0–5.0	4.0–5.0	...	...	7.00–8.00	6.00–7.00	6.0–7.0	4.0–5.0
Titanium	...	[C]	[E]	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Columbium + tantalum	...	...	...	[D]	[F]	[D]	[F]	...	0.10–0.30	...	...	...	...	...	...	...	0.1 max	0.6–1.0	...	...	...	...	...
Tantalum, max	...	...	...	...	...	0.10	0.10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nitrogen[G]	...	...	...	...	...	...	...	...	0.20–0.40	0.20–0.40	...	0.09–0.15	0.18–0.22	0.14–0.20	0.10 max	0.10–0.20	0.4–0.6	...	0.12–0.18	0.45–0.55	0.18–0.25	0.15–0.25	0.10 max
Vanadium	...	...	...	...	...	...	...	...	0.10–0.30	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Others	...	...	...	...	...	...	...	...	...	...	Al 0.8–1.5	...	Cu 0.05–1.00	Ce 0.03–0.08	Cu 0.75 max	Cu 0.75 max	...	Ce 0.05–0.10 Al 0.025 max	Cu 0.03–0.08	Cu 0.30–0.60	Cu 0.75 max	Cu 0.5–1.5	1.0–2.0

NOTES:

[A] New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

[B] For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040% is necessary in Grades TP 304L and TP 316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall are those less than 0.049 in. [1.2 mm] in average wall thickness (0.044 in. [1.1 mm] in minimum wall thickness).

[C] Grade TP 321 shall have a titanium content of not less than five times the carbon content and not more than 0.70%.

[D] Grades TP 347 and TP 348 shall have a columbium plus tantalum content of not less than ten times the carbon content and not more than 1.0%.

[E] Grade TP 321H shall have a titanium content of not less than four times the carbon content and not more than 0.60%.

[F] Grades TP 347H and TP 348H shall have a columbium plus tantalum content of not less than eight times the carbon content and not more than 1.0%.

[G] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

[H] Maximum, unless otherwise indicated.

TABLE 2
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

98

TABLE 3
TENSILE AND HARDNESS REQUIREMENTS[A]

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Rockwell Hardness Number, max
TP201	S20100	95 [655]	38 [260]	35	B95
TP202	S20200	90 [620]	38 [260]	35	B95
TP304	S30400	75 [515]	30 [205]	35	B90
TP304H	S30409	75 [515]	30 [205]	35	B90
TP304L	S30403	70 [485]	25 [170]	35	B90
TP304N	S30451	80 [550]	35 [240]	35	B90
TP304LN	S30453	75 [515]	30 [205]	35	B90
TP305	S30500	75 [515]	30 [205]	35	B90
TP309Cb	S30940	75 [515]	30 [205]	35	B90
TP309H	S30909	75 [515]	30 [205]	35	B90
TP309HCb	S30941	75 [515]	30 [205]	35	B90
TP309S	S30908	75 [515]	30 [205]	35	B90
TP310Cb	S31040	75 [515]	30 [205]	35	B90
TP310H	S31009	75 [515]	30 [205]	35	B90
TP310HCb	S31041	75 [515]	30 [205]	35	B90
TP310S	S31008	75 [515]	30 [205]	35	B90
TP316	S31600	75 [515]	30 [205]	35	B90
TP316H	S31609	75 [515]	30 [205]	35	B90
TP316L	S31603	70 [485]	25 [170]	35	B90
TP316N	S31651	80 [550]	35 [240]	35	B90
TP316LN	S31653	75 [515]	30 [205]	35	B90
TP317	S31700	75 [515]	30 [205]	35	B90
TP317L	S31703	75 [515]	30 [205]	35	B90
TP321	S32100	75 [515]	30 [205]	35	B90
TP321H	S32109	75 [515]	30 [205]	35	B90
TP347	S34700	75 [515]	30 [205]	35	B90
TP347H	S34709	75 [515]	30 [205]	35	B90
TP348	S34800	75 [515]	30 [205]	35	B90
TP348H	S34809	75 [515]	30 [205]	35	B90
TPXM-15	S38100	75 [515]	30 [205]	35	B90
TPXM-19	S20910	100 [690]	55 [380]	35	C25
TPXM-29	S24000	100 [690]	55 [380]	35	B100
. . .	S30615	90 [620]	40 [275]	35	B95
. . .	S31050:				
	t ≤ 0.25 in.	84 [580]	39 [270]	25	B95
	t >0.25 in.	78 [540]	37 [255]	25	B95
. . .	S31254	94 [650]	44 [300]	35	B96
. . .	S30815	87 [600]	45 [310]	35	B95
. . .	S31725	75 [515]	30 [205]	35	B90
. . .	S31726	80 [550]	35 [240]	35	B90
. . .	S24565	115 [795]	60 [415]	35	B100
. . .	S33228	73 [500]	27 [185]	30	B90
. . .	S30415	87 [600]	42 [290]	35	B96
. . .	S32654	109 [750]	62 [430]	35	B100
. . .	N08367				
	t ≤ 0.187	100 [690]	45 [310]	30	100
	t >0.187	95 [655]	45 [310]	30	100
. . .	N08926	94 [650]	43 [295]	35	B100
. . .	N08904	71 [490]	31 [215]	35	B90

[A] Not applicable to tubes less than $\frac{1}{8}$ in. [3.2 mm] in outside diameter or having wall thickness below 0.015 in. [0.4 mm], or both. The tensile properties of such small diameter or thin wall tubes shall be a matter of agreement between the manufacturer and the purchaser.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contact, or order.

S1. Stress-Relieved Annealed Tubes

S1.1 For use in certain corrosives, particularly chlorides where stress corrosion may occur, tubes in Grades TP304L, TP316L, TP321, TP347, and TP348 may be specified in the stress-relieved annealed condition. Details of these supplemental requirements shall be agreed upon by the manufacturer and the purchaser.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1550 to 1650°F [845 to 900°C] after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

S1.3 Straightness of the tubes shall be a matter of negotiation between the purchaser and manufacturer.

S2. Minimum Wall Tubes

S2.1 When specified by the purchaser, tubes shall be furnished on a minimum wall basis. Such tubes shall satisfy the minimum wall thickness requirements of Specification A 450/A 450M rather than the nominal wall requirements of this specification. In addition to the marking required by Section 18, the tubing shall be marked S2.

S3. Air Underwater Pressure Test

98 **S3.1** When specified, the tubing shall be examined by the air underwater pressure test.

S4. Stabilizing Heat Treatment

S4.1 Subsequent to the solution anneal required in Section 6, Grades TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S5. DELETED

S6. Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE 4 — Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S4 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

S7. Weld Decay Test

S7.1 When specified by the purchase order, one sample from each lot of tubing shall be subject to testing in boiling 20% hydrochloric acid.

S7.2 Saw cut the sample, approximately 2 in. length, from a production length of tubing. Then, split the sample longitudinally to allow for easy micrometer measurements. The desire is to split the tube longitudinally 90° on each side of the weld. However, for larger tues, reduce the sample size to fit the Erlenmeyer flask. Thus, cuts shall range from a maximum of 30° on each side of the weld for a 5 in. diameter tube and up to 90° on each side of the weld for tubes with 2.75 in. diameter and less. Cut a similar size section from the balance of the tube opposite the weld consisting of 100% base metal. Remove all burrs and sharp edges by lightly grinding. Remove dust and grease by cleaning with soap and water or other suitable solvents. Then, place both sections from each sample tube in the same flask.

S7.3 Prepare the 20% hydrochloric acid solution by slowly adding reagent grade (37%) hydrochloric acid to an equal volume of distilled water.

NOTE 5: **Warning** — Protect eyes and use rubber gloves when handling acid. Mixing shall be done under a hood and testing shall be run under a hood.

S7.4 The test container shall be a 1-L Erlenmeyer flask equipped with ground-glass joints and an Ahlin condenser. The volume of the solution shall be approximately 700 mL.

S7.5 Measure the thickness of the tube at five locations along the weld area of the one sample section, and at five locations along the base-metal sample section. In both cases, take measurements at approximately 0.4 in. intervals along the section lengths. Make these measurements with a sharp, pointed micrometer accurate to at least 0.001 in.

S7.6 Immerse the sample sections into the solution. Add boiling chips and bring to a boil. Allow the chips to remain boiling throughout the test. The time of testing shall be that which is required to remove 40 to 60% of the original base-metal thickness. (Usually 2 h or less.)

S7.7 At the end of the test period, remove the pair of samples from the solution, rinse with distilled water, and dry.

S7.8 After exposure to the test solution, repeat the tube-thickness measurement as in S7.5.

S7.9 Calculate the corrosion ratio, *R*, as follows:

$$R = \frac{W_o - W}{B_o - B}$$

where:

W_o = average weld-metal thickness before the test,
W = average weld-metal thickness after the test,
B_o = average base-metal thickness before the test, and
B = average base-metal thickness after the test.

S7.9.1 A corrosion ratio of 1.25 or less is satisfactory, but other values may be specified upon agreement between the producer and purchaser.

S8. Special Applications

S8.1 For special applications, such as hydraulic expansion of tubes into tube sheets, there shall be no dimensional indication of the weld. Tubes ordered to this requirement shall bear the additional marking of NB.

S9. Additional Testing of Welded Tubing per ASME Request

S9.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E 273 and E 213 with the rejection criteria referenced in A 450/A 450M.

S9.2 If Practice E 273 is employed, a 100% volumetric inspection of the entire length of each tube shall also be performed using one of the non-destructive electric tests permitted by Specification A 450/A 450M.

S9.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S9.4 In addition to the marking prescribed in Specification A 450/A 450M, “SX” shall be added after the grade designation.

SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED FERRITIC ALLOY-STEEL BOILER AND SUPERHEATER TUBES

SA-250/SA-250M

(Identical with ASTM Specification A 250/A 250M-95) 98

1. Scope

1.1 This specification covers several grades, designated T1, T1a, T1b, T2, T11, T12, and T22, of minimum-wall-thickness, electric-resistance-welded, carbon-molybdenum and chromium-molybdenum alloy-steel, boiler and superheater tubes.

1.2 The tubing sizes and thickness usually furnished to this specification are ½ to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.320 in. [0.9 to 8.1 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 An optional supplementary requirement is provided and, when desired, shall be so stated in the order.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Document

2.1 *ASTM Standard:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (electric-resistance-welded tubes),

3.1.3 Grade (Table 1),

3.1.4 Size (outside diameter or minimum wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirement (11.6),

3.1.7 Test report required (see Certification Section of Specification A 450/A 450M),

3.1.8 Specification designation, and

3.1.9 Special requirements and any supplementary requirements selected.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition Specification A 450/A 450M, unless otherwise provided herein.

5. Manufacture

5.1 The steel shall be killed.

5.2 The tubes shall be made by electric-resistance welding.

6. Heat Treatment

6.1 After welding, or when cold finished, after the final cold-drawing pass, all tubes shall be heat treated and, except as provided in 6.1.1, furnished in the full annealed, isothermal annealed, normalized, or normalized and tempered condition at the option of the manufacturer. If furnished in the normalized and tempered condition, the minimum tempering temperature shall be 1200°F [650°C], except T22 shall be tempered at 1250°F [676°C] minimum.

6.1.1 When grades T1, T1a, T1b, and T2 are cold finished, the tubes may, at the option of the manufacturer, be heat treated after the final cold-drawing pass at a temperature of 1200°F or higher, provided one of the heat treatments specified in 6.1 was applied after welding.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

8. Product Analysis

8.1 An analysis of either one length of flat-rolled stock or one tube shall be made on each heat. The chemical composition thus determined shall conform to the requirements specified.

8.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 1) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 1 — For flattening and flange requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness that are produced from the same heat of steel. When final heat treatment is in batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

NOTE 2 — For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

9. Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

9.2 Table 4 gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00 \; [E = 1.87t + 15.00]$$

where:

E = elongation in 2 in. or 50 mm in %, and
t = actual thickness of specimen, in. [mm].

10. Hardness Requirements

10.1 The tubes shall have a hardness not exceeding the requirements of Table 5.

11. Mechanical Tests Required

11.1 *Tension Test* — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 2).

11.2 *Flattening Test* — One flattening test shall be made on specimens for each end of one finished tube, not the one used for the flange test, from each lot (Note 1).

11.3 *Flange Test* — One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

11.4 *Reverse Flattening Test* — One reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

11.5 *Hardness Test* — Brinell and Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 2).

11.6 *Hydrostatic or Nondestructive Electric Tests* — Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which is to be used.

12. Forming Operations

12.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding and bending operations necessary for application without developing defects.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 450/SA 450M, the marking shall include the words “Electric Resistance-Welded Steel.”

14. Keywords

14.1 boiler tube; resistance welded steel tube; steel tube, alloy; superheater tube; welded steel tube

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %						
Element	Grade T1	Grade T1a	Grade T1b	Grade T2	Grade T11	Grade T12	Grade T22
Carbon	0.10–0.20	0.15–0.25	0.14 max	0.10–0.20	0.05–0.15	0.05–0.15	0.15 max
Manganese	0.30–0.80	0.30–0.80	0.30–0.80	0.30–0.61	0.30–0.60	0.30–0.61	0.30–0.60
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.030	0.025
Sulfur, max	0.025	0.025	0.025	0.020	0.020	0.020	0.020
Silicon	0.10–0.50	0.10–0.50	0.10–0.50	0.10–0.30	0.50–1.00	0.50 max	0.50 max
Molybdenum	0.44–0.65	0.44–0.65	0.44–0.65	0.44–0.65	0.44–0.65	0.44–0.65	0.87–1.13
Chromium	. . .	. . .	. . .	0.50–0.81	1.00–1.50	0.80–1.25	1.90–2.60

TABLE 2
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

Grade	T1	T1a	T1b	T2	T11	T12	T22
Tensile strength, min, ksi [MPa]	55 [380]	60 [415]	53 [365]	60 [415]	60 [415]	60 [415]	60 [415]
Yield strength, min, ksi [MPa]	30 [205]	32 [220]	28 [195]	30 [205]	30 [205]	32 [220]	30 [205]
Elongation in 2 in. or 50 mm, min, %	30	30	30	30	30	30	30
For longitudinal strip tests a deduction shall be made for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points	1.50[A]	1.50[A]	1.50[A]	1.50[A]	1.50[A]	1.50[A]	1.50[A]

[A] See Table 4 for the computed minimum values.

TABLE 4
MINIMUM ELONGATION VALUES

Wall Thickness		Elongation in 2 in. or 50 mm, min, %[A]
in.	mm	Grades T1, T1a, T1b, T2, T11, T12, and T22
$\frac{5}{16}$ (0.312)	8	30
$\frac{9}{32}$ (0.281)	7.2	29
$\frac{1}{4}$ (0.250)	6.4	27
$\frac{7}{32}$ (0.219)	5.6	26
$\frac{3}{16}$ (0.188)	4.8	24
$\frac{5}{32}$ (0.156)	4	22
$\frac{1}{8}$ (0.125)	3.2	21
$\frac{3}{32}$ (0.094)	2.4	20
$\frac{1}{16}$ (0.062)	1.6	18

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

TABLE 5
HARDNESS REQUIREMENTS

Grade	Brinell Hardness Number (Tubes 0.200 in. [5.08 mm] and Over in Wall Thickness)	Rockwell Hardness Number (Tubes Less Than 0.200 in. [5.08 mm] in Wall Thickness)
T1	146	B80
T1a	153	B81
T1b	137	B77
T2	163	B85
T11	163	B85
T12	163	B85
T22	163	B85

SPECIFICATION FOR CORROSION-RESISTING CHROMIUM STEEL-CLAD PLATE, SHEET, AND STRIP

SA-263

(Identical with ASTM Specification A 263-94.) 98

1. Scope

1.1 This specification covers plate, sheet, and strip of a carbon steel or low-alloy steel base to which is integrally and continuously bonded on one or both sides a layer of corrosion-resisting chromium steel. The material is generally intended for pressure vessel use.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 240 Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

2.2 *ASME Code:*

Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Terminology

3.1 *Descriptions of Terms:*

3.1.1 This material is considered as single-clad or double-clad corrosion-resisting chromium-steel plate, sheet, or strip depending on whether one or both sides are covered.

3.1.2 The terms plate, sheet, and strip as used in this specification apply to the following:

3.1.2.1 *plate* — Material $^{3}/_{16}$ in. (2.73 mm) and over in thickness and over 10 in. (254 mm) in width,

3.1.2.2 *sheet* — Material under $^{3}/_{16}$ in. in thickness and 24 in. (609.6 mm) and over in width, material under $^{3}/_{16}$ in. in thickness and all widths and finishes of Nos. 3 to 8 inclusive, and

3.1.2.3 *strip* — Cold-rolled material under 24 in. in width and $^{3}/_{16}$ in. and under in thickness.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following: 98

4.1.1 Quantity (mass or number of pieces).

4.1.2 Name of material (corrosion-resisting chromium steel-clad plate, sheet or strip).

4.1.3 Cladding alloy.

4.1.4 Base metal.

4.1.5 Dimensions including the thickness of the cladding alloy.

4.1.6 Product analysis, if required (see Section 9).

4.1.7 Mechanical properties (see Sections 8, 14, and 15).

4.1.8 Finish (see Section 12).

4.1.9 Restrictions, if required, on repair by welding (see Section 13).

4.1.10 Additions to the specification or special requirements.

5. General Requirements for Delivery

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 20/A 20M.

6. Materials and Manufacture

6.1 *Process:*

6.1.1 The steel shall be made by the open-hearth, electric-furnace (with separate degassing and refining optional), or basic-oxygen processes, or by secondary processes whereby steel made from these primary processes is remelted using electroslag remelting or vacuum-arc remelting processes.

6.1.2 The alloy-cladding metal may be metallurgically bonded to the base metal by any method that will produce a clad steel that will conform to the requirements of this specification.

6.2 *Heat Treatment* — Unless otherwise specified or agreed upon between the purchaser and the manufacturer, all plates shall be furnished in the normalized or tempered condition, or both.

7. Chemical Composition

7.1 The composite plate, sheet, or strip shall conform to any desired combination of alloy-cladding metal and base metal as described in 7.2 and 7.3 and as agreed upon between the purchaser and the manufacturer.

7.2 *Alloy Cladding Metal* — The alloy-cladding metal specified shall conform to the requirements as to chemical composition prescribed for the respective chromium steel in Specification A 240/A 240M.

7.3 *Base Metal* — The base metal may be carbon steel or low-alloy steel conforming to the ASTM specifications for steels for pressure vessels. The base metal shall conform to the chemical requirements of the specification to which it is ordered.

8. Mechanical Properties

8.1 *Plate:*

8.1.1 *Tensile Requirements:*

8.1.1.1 The tensile properties shall be determined by a tension test of the composite plate for clad plates that meet all of the following conditions. However, if the cladding is for corrosion allowance only, the cladding may be removed before tensile testing. The tensile properties thus determined shall be not less than the minimum and not more than 5000 psi (35 MPa) over the maximum prescribed in the specification for the base steel used. All other tensile test requirements of the specification for the base steel shall be met.

(a) The composite gage is less than or equal to $1\frac{1}{2}$ in.

(b) The specified minimum tensile strength of the base steel is less than or equal to 70 000 psi (485 MPa).

(c) The specified minimum yield strength of the base steel is less than or equal to 40 000 psi (275 MPa).

8.1.1.2 The tensile properties shall be determined by a tension test of the base steel only for clad plates that meet one of the following conditions. The properties thus determined shall meet all of the tensile test requirements for the base steel.

(a) The composite gage is greater than $1\frac{1}{2}$ in.

(b) The specified minimum tensile strength of the base steel is greater than 70 000 psi (485 MPa).

(c) The specified minimum yield strength of the base steel is greater than 40 000 psi (275 MPa).

8.1.2 *Ductility* — Two bend tests of the composite plate shall be made, one with the alloy cladding in tension and the other with the alloy cladding in compression, to determine the ductility of the materials. On double-clad plates, the bend tests shall be made so that one specimen represents the alloy cladding in tension on one side while the other specimen represents the alloy cladding in tension on the opposite side. The bend test having the alloy cladding in tension shall be made in accordance with the requirements prescribed in the specifications for the cladding metal. The bend test having the base metal in tension shall be made in accordance with the requirements prescribed in the specifications for the base metal.

8.1.3 *Shear Strength* — When required by the purchaser, the minimum shear strength of the alloy cladding and base metals shall be 20 000 psi (140 MPa). The shear test, when specified, shall be made in the manner indicated in Fig. 1.

8.1.4 *Bond Strength* — As an alternative to the shear strength test provided in 8.1.2 and when required by the purchaser, three bend tests shall be made with the alloy cladding in compression to determine the quality of the bond. These bend tests shall be made in accordance with the specifications for the cladding metal. At least two of the three tests shall show not more than 50% separation on both edges of the bent portion. Greater separation shall be cause for rejection.

8.2 *Sheet and Strip:*

8.2.1 The bend test specimens of sheet and strip shall stand being bent cold, without cracking on the outside of the bent portion, through an angle of 180°.

8.2.2 The bend test specimens shall be bent over a single piece of flat stock of the same thickness as the material tested, allowing the test material to form its natural curvature. The axis of the bend shall be transverse to the direction of rolling.

NOTE 1 — The bend may be made over a diameter equal to the thickness of the test material.

8.2.3 The bond between the alloy cladding and the base metal shall be ascertained by observation of the behavior of the composite sheet or strip when sheared with the alloy side down.

8.3 Methods and practices relating to mechanical testing required by this specification shall be in accordance with Test Methods and Definitions A 370.

9. Product Analysis

9.1 Product analyses may be required on the finished product only when the composite plate thickness is sufficient to permit obtaining drillings or millings without danger of contamination from the adjacent layer.

9.2 If product analysis is specified by the purchaser, it shall be made from drillings or millings taken from the final piece or a broken test specimen. In order to avoid contamination by the base plate metal, cladding samples shall be taken from the test coupon by removal and discard of all the base metal plate material, plus 40% of the cladding thickness from the bonded side, not to exceed $\frac{1}{16}$ in. (1.588 mm). The material shall be chemically cleaned and millings shall be taken to represent the full cross-section of the remainder.

9.3 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

9.4 Results of the product analysis shall conform to the requirements of Section 7 of Specification A 480/A 480M.

10. Dimensions, Mass, and Permissible Variations

10.1 Composite plates, sheets, and strips shall conform to the dimensional and mass requirements prescribed in Tables 1, 2, 3, 4, and 5.

11. Thickness of Cladding Metal

11.1 The minimum thickness and tolerances on the thickness of the alloy-cladding metal shall be agreed upon between the purchaser and the manufacturer.

12. Workmanship, Finish, and Appearance

12.1 The material shall be free of injurious defects, shall have a workmanlike appearance, and shall conform to the designated finish.

12.2 Plate alloy surfaces shall be sand-blasted, pickled, or blast-cleaned and pickled.

12.3 The finish for the alloy surfaces of sheets and strips shall be as specified in the applicable sections of Specification A 240.

13. Repair of Cladding by Welding

13.1 The material manufacturer may repair defects in cladding by welding provided the following requirements are met: 98

13.1.1 Prior approval shall be obtained from the purchaser if the repaired area exceeds 3% of the cladding surface.

13.1.2 The welding procedure and the welders or welding operators shall be qualified in accordance with Section IX of the ASME Code.

13.1.3 The defective area shall be removed and the area prepared for repair shall be examined by a magnetic particle method or a liquid penetrant method

to ensure all defective area has been removed. Method of test and acceptance standard shall be as agreed upon between the purchaser and the manufacturer.

98 **13.1.4** The weld shall be deposited in accordance with a welding procedure and welding materials suitable for the cladding material. The surface condition of the repaired area shall be restored to a condition similar to the rest of the cladding.

13.1.5 The repaired area is examined by a liquid penetrant method in accordance with 13.1.3.

13.1.6 The location and extent of the weld repairs together with the repair procedure and examination results are transmitted as a part of the certification.

13.2 All repairs in Alloy type 410 or repairs penetrating into the base steel shall be stress relieved to eliminate residual stresses.

14. Number of Tests and Retests

14.1 *Plate:*

14.1.1 One or more tension tests, as required by the specifications for the base metal, one face bend test (alloy cladding in tension), one reverse bend test (alloy cladding in compression), and, when specified, one shear test or three bond bend tests shall be made representing each plate as rolled. Each specimen shall be in the final condition of heat treatment required for the plate.

14.1.2 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

14.1.3 If the percentage of elongation of any tension test specimen is less than that specified in 8.1.1 and any part of the fracture is more than $\frac{3}{4}$ in. (19.1 mm) from the center of the gage length of a 2 in. (50.8 mm) specimen or is outside the middle third of the gage length of an 8 in. (203.2 mm) specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

14.2 *Sheet and Strip:*

14.2.1 In the case of single-clad sheet or strip produced in coil form, two bend tests shall be made from each end of the coil. On double-clad sheet or strip produced in coil form, one bend test shall be made from each end of the coil.

14.2.2 In the case of single-clad sheet or strip produced in discrete cut lengths, four bend tests shall be made on each 100 or less pieces of the same heat and nominal thickness, provided the 100 pieces weigh not less than 1000 lbs. In the event that 100 pieces weigh less than 1000 lbs, four bend tests shall be made from each 1000 lbs or less of the same heat and nominal thickness. On double-clad sheet or strip, two bend tests shall be made on each lot as defined in the two preceding sentences.

14.2.3 On double-clad materials, the bend tests shall be made so that one specimen will represent the alloy-cladding metal in tension on one side while the other specimen will represent the alloy-cladding metal in tension on the opposite side.

15. Test Specimens

15.1 *Plate:*

15.1.1 The tension test specimens from plate shall conform to the requirements prescribed in the specifications for the base metal.

15.1.2 Bend test specimens shall be taken from the middle of the top of the plate as rolled, at right angles to its longitudinal axis.

15.1.3 When required by the purchaser, the shear test specimen shall be taken from a top or bottom corner of the plate as rolled, parallel to its longitudinal axis.

15.1.4 All tests shall be made on specimens in the same condition of heat treatment to which the composite plate is furnished.

15.1.5 When specified in the purchase order, additional test specimens representing the as-furnished composite plate shall be thermally treated to simulate a post-weld heat treatment. The temperature range, time, and cooling rates shall be specified in the purchase order. Mechanical properties in the simulated post-weld heat-treated condition shall meet the minimum requirements of the as-furnished composite plate.

15.1.6 For plates $1\frac{1}{2}$ in. (38.1 mm) and under in thickness tension test specimens shall be full thickness of the material except as specified in 8.1.1.1 and 8.1.1.2; the bend test specimen shall be the full thickness of the material and shall be machined to the form and dimensions shown in Fig. 2, or may be machined with both edges parallel.

15.1.7 For plates over $1\frac{1}{2}$ in. in thickness, tension tests shall be of the form shown in Fig. 3 and shall

be of all base steel conforming to the requirements of the specification for the base steel.

15.1.8 For plates over 1½ in. in thickness the bend tests specimens need not be greater in thickness than 1½ in. but shall not be less than 1½ in. Specimens shall be of the form and dimensions shown in Fig. 2. In reducing the thickness of the specimen, both the alloy cladding and the base steel shall be machined so as to maintain the same ratio of clad metal to base steel as is maintained in the plate, except that the thickness of the clad metal need not be reduced below ⅛ in. (3.17 mm).

15.1.9 The sides of the bend test specimen may have the corners rounded to a radius not over 1/16 in. (1.58 mm) for plates, 2 in. (50.8 mm) and under in thickness, and not over ⅛ in. for plates over 2 in. in thickness.

15.2 *Sheet and Strip:*

15.2.1 Bend test specimens from sheet and strip shall be of the full thickness of the material and shall have a width equal to six times the thickness but not less than 1 in. (25.4 mm). The length shall be equal to the width of the sheet or strip but in no case longer than 12 in. (304.8 mm). The edges of the test specimen may be rounded to a radius equal to one half the thickness.

15.2.2 Any test specimen used for the determination of the minimum thickness of alloy-cladding metal shall have distorted metal, due to burning or shearing, completely removed.

16. Inspection

16.1 The manufacturer shall afford the inspector all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

17. Rejection and Rehearing

17.1 Unless otherwise specified, any rejection based on tests made in accordance with Section 9 shall be reported to the manufacturer within 5 working days from the receipt of samples by the purchaser.

17.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's work will be rejected, and the manufacturer shall be notified.

17.3 Samples tested in accordance with Section 9 that represent rejected material shall be preserved for 3 weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

18. Certification

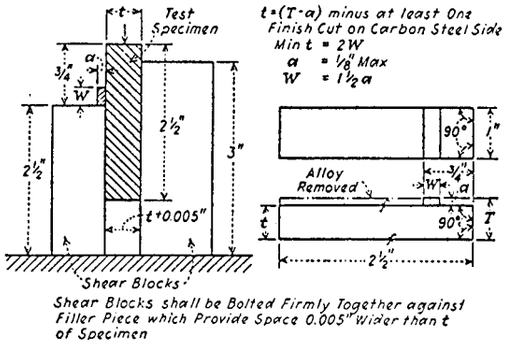
18.1 The chemical analysis of the base metal shall be certified to the purchaser by the manufacturer.

18.2 The results of the tests in Section 8 shall be reported to the purchaser or his representative.

19. Product Marking

19.1 Except as specified in 19.2, the name or brand of the manufacturer, the manufacturer's test identification number, the class of the base steel, the type number of the alloy-cladding metal, and the specified minimum tensile strength shall be legibly stamped on each finished single-clad plate in two places on the base steel side not less than 12 in. (304.8 mm) from the edges. The manufacturer's identification number shall be legibly stamped on each test specimen.

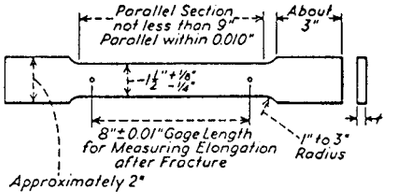
19.2 For double-clad material or for material under ¼ in. (6.35 mm) in thickness, the marking specified in 18.1 shall be legibly stenciled instead of stamped.



Metric Equivalents

in.	mm	in.	mm
0.005	0.127	1	25.4
1/8	3.18	2 1/2	64.5
3/4	19.1	3	76.2

FIG. 1 TEST SPECIMEN AND METHOD OF MAKING SHEAR TEST OF CLAD PLATE



Metric Equivalents

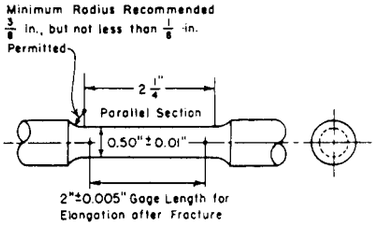
in.	mm.	in.	mm
0.01	0.254	1 1/2	38.1
1/8	3.17	2	50.8
1/4	6.35	3	76.2
1	25.4	8	203.2

NOTE 1—When necessary, it is permissible to use a narrower specimen, but in such a case the reduced portion shall be not less than 1 in. in width.

NOTE 2—Punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the parallel section; either a set of nine punch marks 1 in. apart, or one or more sets of 8-in. punch marks may be used.

NOTE 3—The dimension *t* is the thickness of the test specimen as provided for in the applicable material specifications.

FIG. 2 STANDARD RECTANGULAR TENSION TEST SPECIMEN WITH 8-IN. GAGE LENGTH



Metric Equivalents

in.	mm	in.	mm
0.003	0.076	3/8	9.53
0.005	0.127	0.50	12.7
0.01	0.254	2	50.8
1/8	3.18	2 1/4	64.5

NOTE—The gate length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. larger in diameter than the center.

FIG. 3 STANDARD ROUND TENSION TEST SPECIMEN WITH 2-IN. GAGE LENGTH

TABLE 1
PERMISSIBLE VARIATIONS IN DIMENSIONS AND WEIGHT OF STANDARD SHEET (NO. 1 AND NO. 2 FINISHES)

Specified Thickness, in. (mm)	Permissible Variations in Thichness, ±, in. (mm)
0.005 (0.127)	0.001 (0.025)
0.006 to 0.007 (0.152 to 0.178)	0.0015 (0.038)
0.008 to 0.016 (0.203 to 0.406)	0.002 (0.051)
0.161 to 0.026 (0.409 to 0.660)	0.003 (0.076)
0.027 to 0.040 (0.686 to 1.016)	0.004 (0.102)
0.041 to 0.058 (1.041 to 1.473)	0.005 (0.127)
0.059 to 0.072 (1.499 to 1.829)	0.006 (0.152)
0.073 to 0.083 (1.854 to 2.108)	0.007 (0.178)
0.084 to 0.098 (2.133 to 2.489)	0.008 (0.203)
0.099 to 0.114 (2.515 to 2.896)	0.009 (0.229)
0.115 to 0.130 (2.921 to 3.302)	0.010 (0.254)
0.131 to 0.145 (3.327 to 3.683)	0.012 (0.305)
0.146 to 0.176 (3.709 to 4.470)	0.014 (0.356)

	Permissible Variations in Width, in. (mm)	
Specified Width, in. (mm)[A]	+	−
Up to 42 (1066.8)	1/16 (1.59)	0
42 and Over (1066.8 and Over)	1/8 (3.18)	0

	Permissible Variations in Length, in. (mm)	
Specified Length, in. (mm)[A]	+	−
Up to 120 (3048)	1/16 (1.59)	0
120 and Over (3048 and Over)	1/8 (3.18)	0

Weight Permissible variations in weight apply only to polished finishes. The actual weight of any one item of an ordered thickness and size in any finish is limited in overweight by the following tolerances:	Estimated Permissible Variations, Actual Weight Over the Estimated Weight, %[B]
Any item of 5 sheets or less, or any item estimated to weigh 200 lb (90.72 kg) or less	10
Any item of more than 5 sheets, and estimated to weigh more than 200 lb (90.72 kg)	7.5

[A] Sheet 0.131 in. (3.33 mm) and over in thickness, regardless of size, may have permissible variations of ± 1/4 in. (6.35 mm) in width and in length, respectively.

[B] There is no under variation in weight for No. 1 and No. 2 finishes, these finishes being limited in under variations only by the permissible variations in thickness. Polished sheets may actually weigh as much as 5% less than the estimated weight. Estimated weight of the composite plates may be calculated using the following weights of the component materials:

	Weight per Square Foot for Material 1 in. in Thickness, lb
Steel	40.8
Chromium steel cladding	41.2

TABLE 2
PERMISSIBLE VARIATIONS IN THICKNESS OF COLD-ROLLED STRIP

NOTE — Permissible variations in thickness are based on measurements taken 3/8 in. (9.53 mm) in from the edge on cold-rolled strip 1 in. (25.4 mm) or over in width and at any place on the strip on material less than 1 in. (25.4 mm) in width.

Specified Thickness, in. (mm)	Permissible Variations in Thickness, ±, for Widths Given, in. (mm)									
	3/16 to 1/2 (4.76 to 12.7 mm)	1/2 to 1 (12.7 to 25.4 mm)	1 to 1 1/2 (25.4 to 38.1 mm)	1 1/2 to 3 (38.1 to 76.2 mm)	3 to 6 (76.2 to 152.4 mm)	Over 6 to 9 (152.4 to 228.6 mm)	Over 9 to 12 (228.6 to 304.8 mm)	Over 12 to 16 (304.8 to 406.4 mm)	Over 16 to 20 (406.4 to 508.0 mm)	Over 20 to 23 15/16 (508.0 to 608.1 mm)
0.249 to 0.161 (6.632 to 4.09), incl	0.002 (0.0508)	0.002 (0.0508)	0.003 (0.0762)	0.003 (0.0762)	0.004 (0.1016)	0.004 (0.1016)	0.004 (0.1016)	0.005 (0.1270)	0.006 (0.1524)	0.006 (0.1524)
0.160 to 0.100 (4.08 to 2.54), incl	0.002 (0.0508)	0.002 (0.508)	0.002 (0.508)	0.002 (0.508)	0.003 (0.0762)	0.004 (0.1016)	0.004 (0.1016)	0.004 (0.1016)	0.005 (0.1270)	0.005 (0.1270)
0.099 to 0.069 (2.53 to 1.75), incl	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)	0.004 (0.1016)	0.004 (0.1016)	0.004 (0.1016)
0.068 to 0.050 (1.74 to 1.27), incl	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)	0.004 (0.1016)	0.004 (0.1016)
0.048 to 0.040 (1.26 to 1.02), incl	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.0025 (0.0635)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)	0.004 (0.1016)	0.004 (0.1016)
0.039 to 0.035 (1.01 to 0.88), incl	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.0025 (0.0635)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)
0.034 to 0.032 (0.87 to 0.81) incl	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.002 (0.051)	0.0025 (0.064)	0.0025 (0.064)	0.0025 (0.064)	0.003 (0.076)	0.003 (0.076)
0.031 to 0.029 (0.80 to 0.74), incl	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.002 (0.051)	0.0025 (0.064)	0.0025 (0.064)	0.0025 (0.064)	0.003 (0.076)	0.003 (0.076)
0.028 to 0.026 (0.73 to 0.66), incl	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.002 (0.051)	0.002 (0.051)	0.002 (0.051)	0.0025 (0.064)	0.003 (0.076)
0.025 to 0.023 (0.65 to 0.58), incl	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.002 (0.051)	0.002 (0.051)	0.002 (0.051)	0.0025 (0.064)	0.0025 (0.064)
0.022 to 0.020 (0.57 to 0.51), incl	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.002 (0.051)	0.002 (0.051)	0.002 (0.051)	0.0025 (0.064)	0.0025 (0.064)

TABLE 2 (CONT'D)
PERMISSIBLE VARIATIONS IN THICKNESS OF COLD-ROLLED STRIP

NOTE — Permissible variations in thickness are based on measurements taken 3/8 in. (9.53 mm) in from the edge on cold-rolled strip 1 in. (25.4 mm) or over in width and at any place on the strip on material less than 1 in. (25.4 mm) in width.

Specified Thickness, in. (mm)	Permissible Variations in Thickness, ±, for Widths Given, in. (mm)									
	3/16 to 1/2 (4.76 to 12.7 mm)	1/2 to 1 (12.7 to 25.4 mm)	1 to 1 1/2 (25.4 to 38.1 mm)	1 1/2 to 3 (38.1 to 76.2 mm)	3 to 6 (76.2 to 152.4 mm)	Over 6 to 9 (152.4 to 228.6 mm)	Over 9 to 12 (228.6 to 304.8 mm)	Over 12 to 16 (304.8 to 406.4 mm)	Over 16 to 20 (406.4 to 508.0 mm)	Over 20 to 23 15/16 (508.0 to 608.1 mm)
0.019 to 0.017 (0.50 to 0.43), incl	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)	0.002 (0.051)	0.002 (0.051)	0.002 (0.051)
0.016 to 0.015 (0.42 to 0.38), incl	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.002 (0.051)	0.002 (0.051)
0.014 to 0.013 (0.37 to 0.33), incl	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.002 (0.051)	0.002 (0.051)
0.012 (0.30)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)
0.011 (0.28)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)
0.010 (0.25)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)
0.009 to 0.006 (0.23 to 0.15), incl	0.00075 (0.019)	0.00075 (0.019)	0.00075 (0.019)	0.00075 (0.019)	0.00075 (0.019)	. . .	. . .	. . .	. . .	. . .
Under 0.006 (Under 0.15)	0.0005 (0.013)	0.0005 (0.013)	0.0005 (0.013)	0.0005 (0.013)	0.0005 (0.013)	. . .	. . .	. . .	. . .	. . .

TABLE 3
PERMISSIBLE VARIATIONS IN DIMENSIONS OF COLD-ROLLED STRIP

Edge	Description	Specified Width, in. (mm)	Specified Thickness, in. (mm)	Permissible Variations in Width, ±, in. (mm)[A]
No. 1	Round or Square Edge, Rolled	9/32 (7.14) or under	1/16 (1.59) or under	0.005 (0.125)
		Over 9/32 to 3/4 (7.14 to 19.05), incl	3/32 (2.39) or under	0.005 (0.125)
		Over 3/4 to 5 (19.05 to 127.0), incl	1/8 (3.18) or under	0.005 (0.125)
No. 5	Square rolled or filed, after sitting	9/32 (7.14) or under	1/16 (1.59) or under	0.005 (0.125)
		Over 9/32 to 3/4 (7.14 to 19.05), incl	3/32 (2.39) or under	0.005 (0.125)
		Over 3/4 to 5 (19.05 to 127.0), incl	1/8 (3.18) or under	0.005 (0.125)
		Over 5 to 9 (127.0 to 228.6), incl	1/8 to 0.008 (3.18 to 0.203), incl	
		Over 9 to 20 (228.6 to 508.0), incl	0.105 to 0.015 (2.667 to 0.381)	0.010 (0.254)
		Over 20 to 23 15/16 (508.0 to 608.0), incl	0.080 to 0.023 (2.03 to 0.584)	0.010 (0.254)
				0.015 (0.381)
No. 6	Square edge, rolled	1/2 (12.71) or under	3/16 (4.76) or under	0.010 (0.254)
		Over 1/2 to 15/16 (12.7 to 23.81), incl	3/16 to 0.025 (4.76 to 0.635), incl	1/64 (0.396)
		Over 15/16 to 2 (23.81 to 50.8), incl	1/4 to 0.025 (6.35 to 0.635), incl	1/32 (0.794)
		Over 2 to 6 (50.8 to 152.4), incl	1/4 to 0.225 (6.35 to 5.72), incl	3/64 (1.648)

	Permissible Variations in Width of No. 3 Edge Strip, in. (mm)			
Specified Thickness, in. (mm)	Up to 2 in. (50.8)	Over 2 to 6 in. (50.8 to 152.4)	Over 6 to 12 in. (152.4 to 304.8)	Over 12 to 23 15/16 incl (304.8 to 608.0)
0.050 (1.27) or under	0.007 (0.178)	0.010 (0.254)	0.015 (0.381)	0.015 (0.381)
0.051 to 0.083 (1.28 to 2.11)	0.010 (0.254)	0.012 (0.305)	0.015 (0.038)	0.020 (0.508)
0.084 (2.12) or Over	0.012 (0.305)	0.015 (0.381)	0.018 (0.457)	0.20 (0.508)

Specified Length, ft (cm)	Permissible Variation in Length +, in. (mm)
Up to 5, incl	3/8 (9.53)
Over 5 (152.40) to 10 (304.8), incl	1/2 (12.7)
Over 10 (304.8) to 20 (609.6), incl	5/8 (15.88)
Over 20 (609.6) to 30 (914.4), incl	3/4 (19.05)
Over 30 (914.4) to 40 (1219.2), incl	1 (25.4)
Over 40 (1219.2) to 60 (1828.8), incl	1 1/2 (38.1)
Over 60 (1828.8) to 90 (2743.2), incl	2 (50.8)
Over 90 (2743.2) to 200 (6096.0), incl	2 1/2 (63.5)

Specified Width, in. (mm)	Permissible Camber[B]
1 1/2 and under (38.1 and under)	1/2 in. in any 8 ft length (12.7 mm in any 243.84 cm)
Over 1 1/2 to 23 15/16 (Over 38.1 to 608.0), incl	1/4 in. in any 8 ft length (6.35 mm in any 243.84 cm)

[A] These permissible variations are plus or minus. If variation is desired all one way, double the figure indicated.
[B] Camber shall be determined by placing an 8 ft (243.84 cm) straightedge against the concave side of the strip.

TABLE 4
PERMISSIBLE VARIATIONS IN DIMENSIONS OF HOT-ROLLED STRIP

Specified Thickness, Bwg or in. (mm)	Permissible Variations in Thickness, ±, in. (mm)[A]			
	5 in. (127 mm) and Under in Width	Over 5 to 10, incl (127 to 254 mm) in Width	Over 10 to 15, incl (254 to 381 mm) in Width	Over 15 to $23^{15}/_{16}$, incl (381 to 608 mm) in Width
No. 23 to No 18, incl	0.003 (0.076)	0.004 (0.102)	. . .	. . .
No. 1 to No. 11, incl	0.004 (0.102)	0.005 (0.127)	0.006 (0.152)	0.007 (0.178)
No. 10 to 0.187 (4.75 mm), incl	0.005 (0.127)	0.006 (0.152)	0.007 (0.178)	0.008 (0.203)
0.188 to 0.249 (4.76 to 6.32 mm), incl	0.006 (0.152)	0.007 (0.178)	0.008 (0.203)	0.009 (0.229)

Specified Width, in. (mm)	Permissible Variation in Width, in. (mm)	
	Plus	Minus
Up to 1 (25.4) by No. 16 Bwg and heavier	$1/32$ (0.794)	$1/32$ (0.794)
Up to 1 (25.4) by No. 17 Bwg and lighter	$1/32$ (0.794)	$1/32$ (0.794)
Over 1 to 2 (25.4 to 50.8), incl	$1/32$ (0.794)	$1/32$ (0.794)
Over 2 to 5 (50.8 to 127), incl	$3/64$ (1.911)	$3/64$ (1.911)
Over 5 to 10 (127 to 254), incl	$1/16$ (1.588)	$1/16$ (1.588)
Over 10 to 15 (254 to 381), incl	$3/32$ (2.381)	$3/32$ (2.381)
Over 15 to 20 (381 to 508), incl	$1/8$ (3.175)	$1/8$ (3.175)
Over 20 to $23^{15}/_{16}$ (508 to 608), incl	$5/32$ (3.969)	$5/32$ (3.969)

Specified Length, ft (cm)	Permissible Variations in Length, in. (mm)					
	Up to 3 in. (76.2 mm) in Width		Over 3 to 6 in. (76.2 to 152.4 mm) in Width		Over 6 in. (152.4 mm) in Width	
	Plus	Minus	Plus	Minus	Plus	Minus
Up to 5 (152.4)	$1/4$ (6.35)	0	$3/8$ (9.53)	0	$1/2$ (12.7)	0
Over 5 to 10 (152.4 to 304.8), incl	$3/8$ (9.53)	0	$1/2$ (12.7)	0	$3/4$ (19.1)	0
Over 10 to 20 (304.8 to 609.6), incl	$1/2$ (12.7)	0	$5/8$ (15.88)	0	1 (25.4)	0
Over 20 to 30 (609.6 to 914.4), incl	$3/4$ (19.1)	0	$3/4$ (19.1)	0	$1\frac{1}{4}$ (31.8)	0
Over 30 to 40 (914.4 to 1219.2), incl	1 (25.4)	0	1 (25.4)	0	$1\frac{1}{2}$ (38.1)	0
Over 40 (1219.2)	$1\frac{1}{2}$ (38.1)	0	$1\frac{1}{2}$ (38.1)	0	$1\frac{3}{4}$ (44.5)	0

Permissible Camber

Strip shall be as straight as practicable and not more than $1/4$ in. (6.35 mm) out of line in any 8 ft (243.8 cm) of length, with camber measurement taken on the concave edge.

[A] Thickness measurement shall be taken in $3/8$ in. (9.53 mm) from edge of strip. In the case of center measurements for thickness the permissible variations shall be that for the edge measurement plus the following:

0.001 in. (0.025 mm) for width $1/2$ to $1\frac{1}{2}$ in. (12.77 to 38.1 mm)
0.002 in. (0.051 mm) for width $1\frac{1}{2}$ to $2\frac{1}{2}$ in. (38.1 to 63.5 mm)
0.003 in. (0.076 mm) for width $2\frac{1}{2}$ to 5 in. (63.5 to 127.0 mm)
0.004 in. (0.102 mm) for width 5 to 10 in. (127.0 to 254.0 mm)
0.005 in. (0.127 mm) for width 10 to 15 in. (254.0 to 381.0 mm)
0.006 in. (0.152 mm) for width 15 to $23^{15}/_{16}$ in. (381.0 to 608.1 mm)

TABLE 5
PERMISSIBLE VARIATIONS IN THICKNESS AND OVERWEIGHTS OF PLATES[B]

Thickness[A]

All plates shall be ordered to thickness and not to weight per square foot. No plates shall vary more than 0.01 in. (0.254 mm) under the thickness ordered, and the overweight of each lot[B] in each shipment shall not exceed the amount given in the table below.

Weight[C]

	Permissible Excess in Average Weight per Square Foot Plates for Widths Given in Inches (mm). Expressed in Percentage of Nominal Weight								
Specified Thickness, in. (mm)	Under 48 (1219.2)	48 (1219.2) to 60 (1524.0) excl	60 (1524.0) to 72 (1828.8) excl	72 (1828.8) to 84 (2133.6) excl	84 (2133.6) to 96 (2438.4) excl	96 (2438.4) to 108 (2743.2) excl	108 (2743.2) to 120 (3048.0) excl	120 (3048.0) to 132 (3352.8) excl	132 (3352.8) to 144 (3657.6) excl
3/16 (4.76) to 1/4 (6.35), excl	10.5	12.0	13.5	15.0	18.0	. . .	. . .	. . .	. . .
1/4 (6.35) to 5/16 (7.94), excl	9.0	10.5	12.0	13.5	15.0	18.0	21.0	24.0	28.5
5/16 (7.94) to 3/8 (9.52), excl	7.5	9.0	10.5	12.0	13.5	15.0	18.0	21.0	25.5
3/8 (9.52) to 7/16 (11.11), excl	7.0	7.5	9.0	10.5	12.0	13.5	15.0	18.0	22.5
7/16 (11.11) to 1/2 (12.7), excl	6.0	7.0	7.5	9.0	10.5	12.0	13.5	15.0	19.5
1/2 (12.7) to 5/8 (15.88), excl	5.5	6.0	7.0	7.5	9.0	10.5	12.0	13.5	16.5
5/8 (15.88) to 3/4 (19.05), excl	4.5	5.5	6.0	7.0	7.5	9.0	10.5	12.0	13.5
3/4 (19.05) to 1 (25.4), excl	4.0	4.5	5.5	6.0	7.0	7.5	9.0	10.5	12.0
1 (25.4) or Over	4.0	4.0	4.5	5.5	6.0	7.0	7.5	9.0	10.5

[A] Spot grinding is permitted to remove surface imperfections not to exceed 0.01 in. (0.254 mm) under the specified thickness.
[B] The term "lot" means all of the plates of each group width and each group thickness.
[C] The weight of individual plates shall not exceed the nominal weight by more than one and one-third times the amount prescribed in the above table.

SPECIFICATION FOR STAINLESS CHROMIUM-NICKEL STEEL-CLAD PLATE, SHEET, AND STRIP

SA-264

(Identical with ASTM Specification A 264-94a) 98

1. Scope

1.1 This specification covers plate, sheet, and strip of carbon steel or low-alloy steel base to which is integrally and continuously bonded on one or both sides a layer of stainless chromium-nickel steel. The material is generally intended for pressure vessel use.

1.2 The values stated in inch-pound units are to be regarded as the standard. SI units are provided for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 240 Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

2.2 *ASME Code:*

Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Terminology

3.1 *Description of Terms:*

3.1.1 This material is considered as single-clad or double-clad corrosion-resisting chromium-nickel steel plate, sheet, or strip depending on whether one or both sides are covered.

3.1.2 The term plate, sheet, and strip as used in this specification apply to the following:

3.1.2.1 *plate* — Material $^{3}/_{16}$ in. (2.73 mm) and over in thickness and over 10 in. (254 mm) in width.

3.1.2.2 *sheet* — Material under $^{3}/_{16}$ in. (2.73 mm) in thickness and 24 in. (609.6 mm) and over in width, material under $^{3}/_{16}$ in. in thickness and all widths and finishes of Nos. 3 to 8 inclusive, and

3.1.2.3 *strip* — Cold-rolled material under 24 in. (609.6 mm) in width and $^{3}/_{16}$ in. (2.73 mm) and under in thickness.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following: 98

4.1.1 Quantity (mass or number of pieces),

4.1.2 Name of material (stainless chromium-nickel steel-clad plate, sheet or strip),

4.1.3 Cladding alloy (see Section 7), 98

4.1.4 Base metal (see Section 7), 98

4.1.5 Dimensions including the thickness of the cladding alloy,

4.1.6 Product analysis, if required, (see Section 9),

4.1.7 Mechanical properties (see Sections 8, 9, and 15),

4.1.8 Finish (see Section 12),

4.1.9 Restrictions, if required, on repair by welding (see Section 13), and

4.1.10 Additions to the specification or special requirements.

5. General Requirements for Delivery

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 20/A 20M.

6. Materials and Manufacture

6.1 *Process:*

6.1.1 The steel shall be made by the open-hearth, electric-furnace (with separate degassing and refining optional), or basic-oxygen processes, or by secondary processes whereby steel made from these primary processes is remelted using electroslag remelting or vacuum-arc remelting processes.

6.1.2 The alloy-cladding metal may be metallurgically bonded to the base metal by any method that will produce a clad steel which will conform to the requirements of this specification.

6.2 *Heat Treatment:*

6.2.1 Unless otherwise specified or agreed upon between the purchaser and the manufacturer, all austenitic stainless steel clad plates shall be given a heat treatment consisting of heating to the proper temperature for the solution of the chromium carbides in the cladding followed by individual air cooling. For base metals of air-hardening low-alloy steels the above heat treatment shall be followed by a tempering treatment.

6.2.2 When plates over 1 in. (25.4 mm) in thickness are to be cold formed, the purchaser may specify that such plates be heat treated for grain refinement of the base metal.

7. Chemical Composition

7.1 The composite plate, sheet, or strip may conform to any desired combination of alloy-cladding metal and base metal as described in 7.2 and 7.3 and as agreed upon between the purchaser and the manufacturer.

7.2 *Alloy Cladding Metal* — The alloy-cladding metal specified shall conform to the requirements as to chemical composition prescribed for the respective chromium-nickel or duplex steel in Specification A 240/A 240 M.

7.3 *Base Metal* — The base metal may be carbon steel or low-alloy steel conforming to the ASTM specifications for steel for pressure vessels. The base metal shall conform to the chemical requirements of the specification to which it is ordered.

8. Mechanical Properties

8.1 *Plate:*

8.1.1 *Tensile Requirements:*

8.1.1.1 The tensile properties shall be determined by a tension test of the composite plate for clad plates that meet all of the following conditions. However, if the cladding is for corrosion allowance only, the cladding may be removed prior to tensile testing. The tensile properties thus determined shall be not less than the minimum and not more than 5000 psi (35 MPa) over the maximum prescribed in the specification for the base steel used. All other tensile test requirements of the specification for the base steel shall be met.

(a) The composite gage is less than or equal to $1\frac{1}{2}$ in.

(b) The specified minimum tensile strength of the base steel is less than or equal to 70 000 psi (485 MPa).

(c) The specified minimum yield strength of the base steel is less than or equal to 40 000 psi (275 MPa).

8.1.1.2 The tensile properties shall be determined by a tension test of the base steel only for clad plates that meet one of the following conditions. The tensile properties thus determined shall meet all of the tensile test requirements for the base steel.

(a) The composite gage is greater than $1\frac{1}{2}$ in.

(b) The specified minimum tensile strength of the base steel is greater than 70 000 psi (485 MPa).

(c) The specified minimum yield strength of the base steel is greater than 40 000 psi (275 MPa).

8.1.2 *Ductility* — Two bend tests of the composite plate shall be made, one with the alloy cladding in

tension and the other with the alloy cladding in compression to determine the ductility of the materials. On double-clad plates, the bend tests shall be made so that one specimen represents the alloy cladding in tension on one side while the other specimen represents the alloy cladding in tension on the opposite side. Bend tests shall be made in accordance with the requirements prescribed in the specification for the base metal.

8.1.3 *Shear Strength* — When required by the purchaser, the minimum shear strength the alloy cladding and base metals shall be 20 000 psi (140 MPa). The shear test, when specified, shall be made in the manner indicated in Fig. 1.

8.1.4 *Bond Strength* — As an alternative to the shear strength test provided in 8.1.3 and when required by the purchaser, three bend tests shall be made with the alloy cladding in compression to determine the quality of the bond. These bend tests shall be made in accordance with the specifications for the cladding metal. At least two of the three tests shall show not more than 50% separation on both edges of the bent portion. Greater separation shall be cause for rejection.

8.2 *Sheet and Strip:*

8.2.1 The bend test specimens of sheet and strip shall stand being bent cold through an angle of 180° without cracking on the outside of the bent portion. The bend test specimens shall be bent around a pin the diameter of which is equal to the thickness of the material. The axis of the bend shall be transverse to the direction of rolling.

8.2.2 The bond between the alloy cladding and the base metal shall be ascertained by observation of the behavior of the composite sheet or strip when sheared with the alloy side down.

8.3 Methods and practices relating to mechanical testing required by this specification shall be in accordance with Test Methods and Definitions A 370.

9. Product Analysis

9.1 Product analysis may be required on finished product. Chemical analysis may be accomplished by wet chemical or instrumental procedures. If wet chemical procedures are used, millings may be taken only when the composite plate thickness is sufficient to permit obtaining millings without danger of contamination from the adjacent layer. If spectrometric procedures are used, the sample shall be exposed on the center line of the cladding when where there is sufficient cladding thickness available so that there is no contamination from the adjacent base metal.

9.2 If product analysis is specified by the purchaser, it shall be made on a sample taken from the finished product or a broken test specimen. For wet chemical analysis, in order to avoid contamination by the base plate metal, millings of cladding samples shall be taken from the test coupon by removal and discard of all the base metal plus 40% of the cladding thickness from the bonded side, not to exceed $\frac{1}{16}$ in. (1.598 mm). The material shall be cleaned and sufficient millings taken to represent the full cross-section of the remainder. If there is insufficient cladding thickness available to spectrographically expose on the center line of the cladding without contamination, 50% of the cladding shall be removed and the sample exposed on this surface.

9.3 The results of the product analysis shall conform to the requirements of Section 7 of Specification A 480/A 480M.

9.4 Methods and practices relating the chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Definitions A 751.

10. Dimensions, Mass, and Permissible Variations

10.1 Composite plates, sheets, and strips shall conform to the dimensional and weight requirements prescribed in Tables 1, 2, 3, 4, and 5.

11. Thickness of Cladding Metal

11.1 The minimum thickness and tolerances on the thickness of the alloy-cladding metal shall be agreed upon between the purchaser and the manufacturer.

12. Workmanship, Finish, and Appearance

12.1 The material shall be free of injurious defects, shall have a workmanlike appearance, and shall conform to the designated finish.

12.2 Plate alloy surfaces shall be sand-blasted, pickled, or blast-cleaned and pickled.

12.3 The finish for the alloy surfaces of sheets and strips shall be as specified in Specification A 240/A 240 M.

13. Repair of Cladding by Welding

13.1 The material manufacturer may repair defects in cladding by welding provided the following requirements are met:

13.1.1 Prior approval shall be obtained from the purchaser if the repaired area exceeds 3% of the cladding surface.

13.1.2 The welding procedure and the welders or welding operators shall be qualified in accordance with Section IX of the ASME Code.

13.1.3 The defective area shall be removed and the area prepared for repair shall be examined by a magnetic particle method or a liquid penetrant method to ensure that all of the defective area has been removed. Method of test and acceptance standard shall be as agreed upon between the purchaser and the manufacturer.

13.1.4 The repair weld shall be deposited in accordance with a welding procedure and welding materials suitable for the cladding material. The surface condition of the repaired area shall be restored to a condition similar to the rest of the cladding.

13.1.5 The repaired area shall be examined by a liquid penetrant method in accordance with 13.1.3.

13.1.6 The location and extent of the weld repairs together with the repair procedure and examination results shall be transmitted as a part of the certification.

13.2 At the request of the purchaser or his inspector, plates shall be reheat treated following repair by welding.

14. Number of Test and Retests

14.1 *Plate:*

14.1.1 One or more tension tests, as required by the specifications for the base metal, one face bend test (alloy cladding in tension), one reverse bend test (alloy cladding in compression), and, when specified, one shear test or three bond bend tests shall be made representing each plate as rolled. Each specimen shall be in the final condition of heat treatment required for the plate.

14.1.2 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

14.1.3 If the percentage of elongation of any tension test specimen is less than that specified in 8.1.1 and any part of the fracture is more than $\frac{3}{4}$ in. (19.1 mm) from the center of the gage length of a 2 in. (50.9 mm) specimen or is outside the middle third of the gage length of an 8 in. (203.2 mm) specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

14.2 *Sheet and Strip:*

14.2.1 In the case of single-clad sheet or strip produced in coil form, two bend tests shall be made from each end of the coil. On double-clad sheet or strip produced in coil form, one bend test shall be made from each end of the coil.

14.2.2 In the case of single-clad sheet or strip produced in discrete cut lengths, four bend tests shall be made on each 100 or less pieces of the same heat and nominal thickness, provided the 100 pieces weigh not less than 1000 lbs. In the event that 100 pieces weigh less than 1000 lbs, four bend tests shall be made from each 1000 lbs or less of the same heat and nominal thickness. On double-clad sheet or strip, two bend tests shall be made on each lot as defined in the two preceding sentences.

14.2.3 On double-clad materials, the bend tests shall be made so that one specimen will represent the alloy-cladding metal in tension on one side while the other specimen will represent the alloy-cladding metal in tension on the opposite side.

15. Test Specimens

15.1 *Plate:*

15.1.1 The tension test specimens from plate shall conform to the requirements prescribed in the specifications for the base metal.

15.1.2 Bend test specimens, shall be taken from the middle of the top of the plate as rolled, at right angles to its longitudinal axis.

15.1.3 When required by the purchaser, the shear test specimen shall be taken from a top or bottom corner of the plate as rolled, parallel to its longitudinal axis.

15.1.4 All tests shall be made on specimens in the same condition of heat treatment to which the composite plate is furnished.

15.1.5 When specified in the purchase order, additional test specimens representing the as-furnished composite plate shall be thermally treated to simulate a post-weld heat treatment. The temperature range, time, and cooling rates shall be specified in the purchase

order. Mechanical properties in the simulated post-weld heat-treated condition shall meet the minimum requirements of the as-furnished composite plate.

15.1.6 For plates 1½ in. (38.1 mm) and under in thickness, tension test specimens shall be the full thickness of the material, except as specified in 8.1.1.1 and 8.1.1.2, and the bend test specimen shall be full thickness of the material and shall be machined to the form and dimension shown in Fig. 2, or may be machined with both edges parallel.

15.1.7 For plates over 1½ in. (38.1 mm) in thickness, tension tests shall be of the form shown in Fig. 3 and shall be of all base steel conforming to the requirements of the specification from the base steel.

5.1.8 For plates over 1½ in. (38.1 mm) in thickness, the bend test specimens need not be greater in thickness than 1½ in. but shall not be less than 1½ in. Specimens shall be of the form and dimensions shown in Fig. 2. In reducing the thickness of the specimen, both the alloy cladding and the base steel shall be machined so as to maintain the same ratio of clad metal to base steel as is maintained in the plate, except that the thickness of the clad metal need not be reduced below ⅛ in. (3.17).

15.1.9 The side of the bend test specimen may have the corners rounded to a radius not over 1/16 in. (1.58 mm) for plates, 2 in. (50.8 mm) and under in thickness, and not over ⅛ in. (3.17 mm) for plates over 2 in. in thickness.

15.2 *Sheet and Strip:*

15.2.1 Bend test specimens from sheet and strip shall be of the full thickness of the material and shall have a width equal to six times the thickness but not less than 1 in. (25.4 mm). The length shall be equal to the width of the sheet or strip but in no case longer than 12 in. (304.8 mm). The edges of the test specimen may be rounded to a radius equal to one half the thickness.

15.2.2 Any test specimen used for the determination of the minimum thickness of alloy-cladding metal shall have distorted metal, due to burning or shearing completely removed.

16. Inspection

16.1 The manufacturer shall afford the inspector all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

17. Rejection and Rehearing

17.1 Unless otherwise specified, any rejection based on tests made in accordance with Section 9 shall be reported to the manufacturer within five working days from the receipt of samples by the purchaser.

17.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's work will be rejected, and the manufacturer shall be notified.

17.3 Samples tested in accordance with Section 9 that represent rejected material shall be preserved for 3 weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for rehearing within that time.

18. Certification

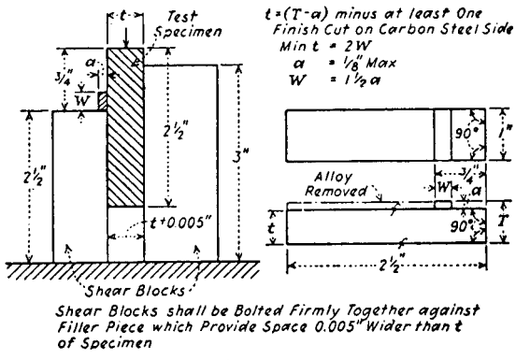
18.1 The chemical analysis of the base metal shall be certified to the purchaser by the manufacturer.

18.2 The results of the tests in Section 8 shall be reported to the purchaser or his representative.

19. Product Marking

19.1 Except as specified in 19.2, the name or brand of the manufacturer, the manufacturer's test identification number, the class of the base steel, the type number of the alloy-cladding metal and the specified minimum tensile strength shall be legibly stamped on each finished single-clad plate in two places on the base steel side not less than 12 in. (304.8 mm) from the edges. The manufacturer's identification number shall be legibly stamped on each test specimen.

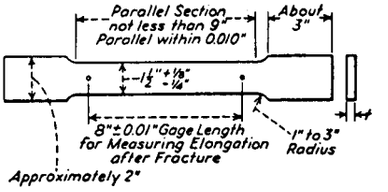
19.2 For double-clad material or for material under ¼ in. (6.35 mm) in thickness, the marking specified in 19.1 shall be legibly stenciled instead of stamped.



Metric Equivalents

in.	mm	in.	mm
0.005	0.127	1	25.4
1/8	3.18	2 1/2	64.5
3/4	19.1	3	76.2

FIG. 1 TEST SPECIMEN AND METHOD OF MAKING SHEAR TEST OF CLAD PLATE



Metric Equivalents

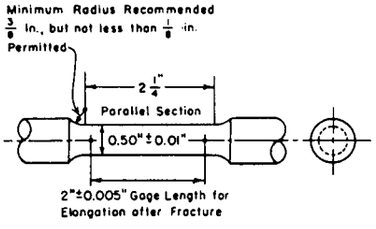
in.	mm	in.	mm
0.01	0.254	1 1/2	38.1
1/8	3.17	2	50.8
1/4	6.35	3	76.2
1	25.4	8	203.2

NOTE 1—When necessary, it is permissible to use a narrower specimen, but in such a case the reduced portion shall be not less than 1 in. in width.

NOTE 2—Punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the parallel section; either a set of nine punch marks 1 in. apart, or one or more sets of 8-in. punch marks may be used.

NOTE 3—The dimension *t* is the thickness of the test specimen as provided for in the applicable material specifications.

FIG. 2 STANDARD RECTANGULAR TENSION TEST SPECIMEN WITH 8-IN. GAGE LENGTH



Metric Equivalents

in.	mm	in.	mm
0.003	0.076	3/8	9.53
0.005	0.127	0.50	12.7
0.01	0.254	2	50.8
1/8	3.18	2 1/4	64.5

NOTE—The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holders of the testing machine in such a way that the load shall be axial. The reduced section shall be a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. larger in diameter than the center.

FIG. 3 STANDARD ROUND TENSION TEST SPECIMEN WITH 2-IN. GAGE LENGTH

TABLE 1
PERMISSIBLE VARIATIONS IN THICKNESS OF COLD-ROLLED STRIP

NOTE — Permissible variations in thickness are based on measurements taken 3/8 in. (9.53 mm) in from the edge on cold-rolled strip 1 in. (25.4 mm) or over in width, and at any place on the strip on material less than 1 in. (25.4 mm) in width.

	Permissible Variations in Thickness, ±, for Widths Given, in. (mm)									
Specified Thickness, in. (mm)	3/16 to 1/2 (4.76 to 12.7)	1/2 to 1 (12.7 to 25.4)	1 to 1 1/2 (25.4 to 38.1)	1 1/2 to 3 (38.1 to 76.2)	3 to 6 (76.2 to 152.4)	Over 6 to 9 (152.4 to 228.6)	Over 9 to 12 (228.6 to 304.8)	Over 12 to 16 (304.8 to 406.4)	Over 16 to 20 (406.4 to 508.0)	Over 20 to 23 15/16 (508.0 to 608.1)
0.249 to 0.161 (6.632 to 4.09) incl	0.002 (0.0508)	0.002 (0.0508)	0.003 (0.0762)	0.003 (0.0762)	0.004 (0.1016)	0.004 (0.1016)	0.004 (0.1016)	0.005 (0.1270)	0.006 (0.1524)	0.006 (0.1524)
0.160 to 0.100 (4.08 to 2.54), incl	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.003 (0.0762)	0.004 (0.1016)	0.004 (0.1016)	0.004 (0.1016)	0.005 (0.1270)	0.005 (0.1270)
0.099 to 0.069 (2.53 to 1.75), incl	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)	0.004 (0.1016)	0.004 (0.1016)	0.004 (0.1016)
0.068 to 0.050 (1.74 to 1.27), incl	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)	0.004 (0.1016)	0.004 (0.1016)
0.049 to 0.040 (1.26 to 1.02), incl	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.0025 (0.0635)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)	0.004 (0.1016)	0.004 (0.1016)
0.039 to 0.035 (1.01 to 0.88), incl	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.002 (0.0508)	0.0025 (0.0635)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)	0.003 (0.0762)
0.034 to 0.032 (0.87 to 0.81) incl	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.002 (0.051)	0.0025 (0.064)	0.0025 (0.064)	0.0025 (0.064)	0.003 (0.0762)	0.003 (0.0762)
0.031 to 0.029 (0.80 to 0.74), incl	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.002 (0.051)	0.0025 (0.064)	0.0025 (0.064)	0.0025 (0.064)	0.003 (0.0762)	0.003 (0.0762)
0.028 to 0.026 (0.73 to 0.66), incl	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.002 (0.051)	0.002 (0.051)	0.002 (0.051)	0.0025 (0.064)	0.003 (0.0762)
0.025 to 0.023 (0.65 to 0.58), incl	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.002 (0.051)	0.002 (0.051)	0.002 (0.051)	0.0025 (0.064)	0.0025 (0.064)
0.022 to 0.020 (0.57 to 0.51), incl	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.002 (0.051)	0.002 (0.051)	0.002 (0.051)	0.0025 (0.064)	0.0025 (0.064)
0.019 to 0.017 (0.50 to 0.43), incl	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)	0.002 (0.051)	0.002 (0.051)	0.002 (0.051)
0.016 to 0.015 (0.42 to 0.38), incl	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.002 (0.051)	0.002 (0.051)
0.014 to 0.013 (0.37 to 0.33), incl	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.002 (0.051)	0.002 (0.051)
0.012 (0.30)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)
0.011 (0.28)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)	0.0015 (0.038)
0.010 (0.25)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.001 (0.025)	0.0015 (0.038)	0.0015 (0.038)
0.009 to 0.006 (0.23 to 0.15), incl	0.00075 (0.019)	0.00075 (0.019)	0.00075 (0.019)	0.00075 (0.019)	0.00075 (0.019)	. . .	. . .	. . .	. . .	. . .
Under 0.006 (Under 0.15)	0.005 (0.013)	0.005 (0.013)	0.005 (0.013)	0.005 (0.013)	0.005 (0.013)	. . .	. . .	. . .	. . .	. . .

TABLE 2
PERMISSIBLE VARIATIONS IN DIMENSIONS AND WEIGHT OF STANDARD SHEET (NO. 1 AND NO. 2 FINISHES)

Specified Thickness, in. (mm)	Permissible Variations in Thichness, ±, in. (mm)
0.005 (0.127)	0.001 (0.025)
0.006 to 0.007 (0.152 to 0.178)	0.0015 (0.038)
0.008 to 0.016 (0.203 to 0.406)	0.002 (0.051)
0.0161 to 0.026 (0.409 to 0.660)	0.003 (0.076)
0.027 to 0.040 (0.686 to 1.016)	0.004 (0.102)
0.041 to 0.058 (1.041 to 1.473)	0.005 (0.127)
0.059 to 0.072 (1.499 to 1.829)	0.006 (0.152)
0.073 to 0.083 (1.854 to 2.108)	0.007 (0.178)
0.084 to 0.098 (2.133 to 2.489)	0.008 (0.203)
0.099 to 0.114 (2.515 to 2.896)	0.009 (0.229)
0.115 to 0.130 (2.921 to 3.302)	0.010 (0.254)
0.131 to 0.145 (3.327 to 3.683)	0.012 (0.305)
0.146 to 0.176 (3.708 to 4.470)	0.014 (0.356)

	Permissible Variations in Width, in. (mm)	
Specified Width, in. (mm)[A]	Plus	Minus
Up to 42 (1066.8)	1/16 (1.59)	0
42 and Over (1066.8 and Over)	1/8 (3.18)	0

	Permissible Variations in Length, in. (mm)	
Specified Length, in. (mm)[A]	Plus	Minus
Up to 120 (3048)	1/16 (1.59)	0
120 and Over (3048 and Over)	1/8 (3.18)	0

Weight Permissible variations in weight apply only to polished finishes. The actual weight of any one item of an ordered thickness and size in any finish is limited in overweight by the following tolerances:	Estimated Permissible Variations, Actual Weight Over the Estimated Weight, %[B]
Any item of 5 sheets or less, or any item estimated to weigh 200 lb (90.72 kg) or less	10
Any item of more than 5 sheets, and estimated to weigh more than 200 lb (90.72 kg)	7.5

[A] Sheet 0.131 in. (3.33 mm) and over in thickness, regardless of size, may have permissible variations of ± 1/4 in. (6.35 mm) in width and in length, respectively.

[B] There is no under variation in weight for No. 1 and No. 2 finishes, these finishes being limited in under variations only by the permissible variations in thickness. Polished sheets may actually weigh as much as 5% less than the estimated weight. Estimated weight of the composite plates may be calculated using the following weights of the component materials:

	Weight per Square Foot for Material 1 in. in Thickness, lb
Steel	40.8
Chromium steel cladding	41.2

TABLE 3
PERMISSIBLE VARIATIONS IN DIMENSIONS OF COLD-ROLLED STRIP

Edge Description	Specified Width, in. (mm)	Specified Thickness, in.(mm)	Permissible Variations in Width, ±, in. (mm)[A]
No. 1 Round or square edge, rolled	9/32 (7.14) or under	1/16 (1.59) or under	0.005 (0.125)
	Over 9/32 to 3/4 (7.14 to 19.05), incl	3/32 (2.39) or under	0.005 (0.125)
	Over 3/4 to 5 (19.05 to 127.0), incl	1/8 (3.18) or under	0.005 (0.125)
No. 5 Square rolled or filed, after slitting	9/32 (7.14) or under	1/16 (1.59) or under	0.005 (0.125)
	Over 9/32 to 3/4 (7.14 to 19.05), incl	3/32 (2.39) or under	0.005 (0.125)
	Over 3/4 to 5 (19.05 to 127.0), incl	1/8 (3.18) or under	0.005 (0.125)
	Over 5 to 9 (127.0 to 228.6), incl	1/8 to 0.008 (3.18 to 0.203), incl	0.010 (0.254)
	Over 9 to 20 (228.6 to 508.0), incl	0.105 to 0.015 (2.667 to 0.381)	0.010 (0.254)
	Over 20 to 23 15/16 (508.0 to 608.0), incl	0.080 to 0.023 (2.03 to 0.584)	0.015 (0.381)
No. 6 Square edge, rolled	1/2 (12.71) or under	3/16 (4.76) or under	0.010 (0.254)
	Over 1/2 to 15/16 (12.7 to 23.81), incl	3/16 to 0.025 (4.76 to 0.635), incl	1/64 (0.396)
	Over 15/16 to 2 (23.81 to 50.8), incl	1/4 to 0.025 (6.35 to 0.635), incl	1/32 (0.794)
	Over 2 to 6 (50.8 to 152.4), incl	1/4 to 0.225 (6.35 to 5.72), incl	5/64 (1.648)

	Permissible Variations in Width of No. 3 Edge Strip, in. (mm)[A]			
Specified Thickness, in. (mm)	Up to 2 in. (50.8)	Over 2 to 6 in. (50.8 to 152.4)	Over 6 to 12 in. (152.4 to 304.8)	Over 12 to 23 15/16 incl (304.8 to 608.0)
0.050 (1.27) or under	0.007 (0.178)	0.010 (0.254)	0.015 (0.381)	0.015 (0.381)
0.051 to 0.083 (1.28 to 2.11)	0.010 (0.254)	0.012 (0.305)	0.015 (0.381)	0.020 (0.508)
0.084 (2.12) or Over	0.012 (0.305)	0.015 (0.381)	0.018 (0.457)	0.020 (0.508)

Specified Length, ft (cm)	Permissible Variation in Length, ±, in. (mm)
Up to 5, incl	3/8 (9.53)
Over 5 (152.40) to 10 (304.8), incl	1/2 (12.7)
Over 10 (304.8) to 20 (609.6), incl	5/8 (15.88)
Over 20 (609.6) to 30 (914.4), incl	3/4 (19.05)
Over 30 (914.4) to 40 (1219.2), incl	1 (25.4)
Over 40 (1219.2) to 60 (1828.8), incl	1 1/2 (38.1)
Over 60 (1828.8) to 90 (2743.2), incl	2 (50.8)
Over 90 (2743.2) to 200 (6096.0), incl	2 1/2 (63.5)

Specified Width, in. (mm)	Permissible Camber[B]
1 1/2 and under (38.1 and under)	1/2 in. in any 8 ft length (12.7 mm in any 243.84 cm)
Over 1 1/2 to 23 15/16 (Over 38.1 to 608.0), incl	1/4 in. in any 8 ft length (6.35 mm in any 243.84 cm)

[A] These permissible variations are plus or minus. If variation is desired all one way, double the figure indicated.
[B] Camber shall be determined by placing an 8 ft (243.84 cm) straightedge against the concave side of the strip.

TABLE 4
PERMISSIBLE VARIATIONS IN DIMENSIONS OF HOT-ROLLED STRIP

Specified Thickness, Bwg or in. (mm)	Permissible Variations in Thickness, ±, in. (mm)[A]			
	5 in. (127 mm) and Under in Width	Over 5 to 10, incl (127 to 254 mm) in Width	Over 10 to 15, incl (254 to 381 mm) in Width	Over 15 to 23 15/16, incl (381 to 608 mm) in Width
No. 23 to No. 18, incl	0.003 (0.076)	0.004 (0.102)	. . .	. . .
No. 17 to No. 11, incl	0.004 (0.102)	0.005 (0.127)	0.006 (0.152)	0.007 (0.178)
No. 10 to 0.187 (4.75), incl	0.005 (0.127)	0.006 (0.152)	0.007 (0.178)	0.008 (0.203)
0.188 to 0.249 (4.76 to 6.32), incl	0.006 (0.152)	0.007 (0.178)	0.008 (0.203)	0.009 (0.229)

Specified Width, in. (mm)	Permissible Variation in Width, in. (mm)	
	Plus	Minus
Up to 2 (25.4 to 50.8), incl	1/32 (0.794)	1/32 (0.794)
Over 2 to 5 (50.8 to 127), incl	3/64 (1.911)	3/64 (1.911)
Over 5 to 10 (127 to 254), incl	1/16 (1.588)	1/16 (1.588)
Over 10 to 15 (254 to 381), incl	3/32 (2.381)	3/32 (2.381)
Over 15 to 20 (381 to 508), incl	1/8 (3.175)	1/8 (3.175)
Over 20 to 23 15/16 (508 to 608), incl	5/32 (3.969)	5/32 (3.969)

Specified Length, ft (cm)	Permissible Variations in Length, in. (mm)					
	Up to 3 in. (76.2 mm) in Width		Over 3 to 6 in. (76.2 to 152.4 mm) in Width		Over 6 in. (152.4 mm) in Width	
	+	−	+	−	+	−
Up to 5 (152.4)	1/4 (6.35)	0	3/8 (9.53)	0	1/2 (12.7)	0
Over 5 to 10 (152.4 to 304.8), incl	3/8 (9.53)	0	1/2 (12.7)	0	3/4 (19.1)	0
Over 10 to 20 (304.8 to 609.6), incl	1/2 (12.7)	0	5/8 (15.88)	0	1 (25.4)	0
Over 20 to 30 (609.6 to 914.4), incl	3/4 (19.1)	0	3/4 (19.1)	0	1 1/4 (31.8)	0
Over 30 to 40 (914.4 to 1219.2), incl	1 (25.4)	0	1 (25.4)	0	1 1/2 (38.1)	0
Over 40 (1219.2)	1 1/2 (38.1)	0	1 1/2 (38.1)	0	1 3/4 (44.5)	0

Permissible Camber

Strip shall be as straight as practicable and not more than 1/4 in. (6.35 mm) out of line in any 8 ft (2.44 mm) of length, with camber measurement taken on the concave edge.

[A] Thickness measurement shall be taken 3/8 in. (9.53 mm) from edge to strip. In the case of center measurements for thickness the permissible variations shall be that for the edge measurement plus the following:

0.001 in. (0.025 mm) for width 1/2 to 1 1/2 in. (12.77 to 38.1 mm)
0.002 in. (0.051 mm) for width 1 1/2 to 2 1/2 in. (38.1 to 63.5 mm)
0.003 in. (0.076 mm) for width 2 1/2 to 5 in. (63.5 to 127.0 mm)
0.004 in. (0.102 mm) for width 5 to 10 in. (127.0 to 254.0 mm)
0.005 in. (0.127 mm) for width 10 to 15 in. (254.0 to 381.0 mm)
0.006 in. (0.152 mm) for width 15 to 23 15/16 in. (381.0 to 608.1 mm)

TABLE 5
PERMISSIBLE VARIATIONS IN THICKNESS AND OVERWEIGHTS OF PLATES

Thickness[A]

All plates shall be ordered to thickness and not to weight per square foot. No plates shall vary more than 0.01 in. (0.254 mm) under the thickness ordered, and the overweight of each lot[B] in each shipment shall not exceed the amount given in the table below.

Weight[C]

Specified Thickness, in. (mm)	Permissible Excess in Average Weight per Square Foot Plates for Widths Given in Inches (mm). Expressed in Percentage of Nominal Weight								
	Under 48 (1219.2)	48 (1219.2) to 60 (1524.0), excl	60 (1524.0) to 72 (1828.8), excl	72 (1828.8) to 84 (2133.6), excl	84 (2133.6) to 96 (2438.4), excl	96 (2438.4) to 108 (2743.2), excl	108 (2743.2) to 120 (3048.0), excl	120 (3048.0) to 132 (3352.8), excl	132 (3352.8) to 144 (3657.6), excl
3/16 (4.76) to 1/4 (6.35), excl	10.5	12.0	13.5	15.0	18.0	. . .	. . .	. . .	. . .
1/4 (6.35) to 5/16 (7.94), excl	9.0	10.5	12.0	13.5	15.0	18.0	21.0	24.0	28.5
5/16 (7.94) to 3/8 (9.52), excl	7.5	9.0	10.5	12.0	13.5	15.0	18.0	21.0	25.5
3/8 (9.52) to 7/16 (11.11), excl	7.0	7.5	9.0	10.5	12.0	13.5	15.0	18.0	22.5
7/16 (11.11) to 1/2 (12.7), excl	6.0	7.0	7.5	9.0	10.5	12.0	13.5	15.0	19.5
1/2 (12.7) to 5/8 (15.88), excl	5.5	6.0	7.0	7.5	9.0	10.5	12.0	13.5	16.5
5/8 (15.88) to 3/4 (19.05), excl	4.5	5.5	6.0	7.0	7.5	9.0	10.5	12.0	13.5
3/4 (19.05) to 1 (25.4), excl	4.0	4.5	5.5	6.0	7.0	7.5	9.0	10.5	12.0
1 (25.4) or Over	4.0	4.0	4.5	5.5	6.0	7.0	7.5	9.0	10.5

[A] Spot grinding is permitted to remove surface imperfections not to exceed 0.01 in. (0.254 mm) under the specified thickness.
[B] The term ''lot'' means all of the plates of each group width and each group thickness.
[C] The weight of individual plates shall not exceed the nominal weight by more than one and one-third times the amount prescribed in the above table.

SPECIFICATION FOR NICKEL AND NICKEL-BASE ALLOY-CLAD STEEL PLATE

SA-265

(Identical with ASTM Specification A 265-94a) 98

1. Scope

1.1 This specification covers plate of a carbon steel or low-alloy steel base to which is integrally and continuously bonded on one or both sides a layer of nickel or nickel-base alloy. The material is generally intended for pressure vessel use.

1.2 The values stated in inch-pound units are to be regarded as the standard. SI units are provided for information only.

2. Referenced Documents

98 **2.1** *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

B 127 Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip

B 162 Specification for Nickel Plate, Sheet, and Strip

B 168 Specification for Nickel-Chromium-Iron Alloy (UNS N06600, N06601, and N06690) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheet, and Strip

B 333 Specification for Nickel-Molybdenum Alloy Plate, Sheet, and Strip

B 409 Specification for Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip

B 424 Specification for Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08221) Plate, Sheet, and Strip

B 443 Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) Plate, Sheet, and Strip

B 463 Specification for UNS N08020, UNS N08026, and UNS N08024 Alloy Plate, Sheet, and Strip

B 575 Specification for Low-Carbon Nickel-Molybdenum-Chromium and Low-Carbon Nickel-Chromium Molybdenum Alloy Plate, Sheet, and Strip

B 582 Specification for Nickel-Chromium-Iron-Molybdenum-Copper Alloy Plate, Sheet, and Strip

B 625 Specification for UNS N08904, UNS N08925, UNS N08931, UNS N08932, and UNS N08926 Plate, Sheet, and Strip

2.2 *ASME Code:*

Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Terminology

3.1 *Descriptions of Terms:*

3.1.1 This material is considered as single-clad or double-clad nickel or nickel-base alloy clad steel plate, depending on whether one or both sides are covered.

3.1.2 The term plate as used in this specification applies to material $^{3}/_{16}$ in. (2.73 mm) and over in thickness, and over 10 in. (254 mm) in width.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to the following: 98

4.1.1 Quantity (mass or number of pieces),

4.1.2 Name of material (Nickel or Nickel-Base Alloy-Clad Steel Plate),

4.1.3 Heat treatment, if required,

4.1.4 Dimensions including the thickness of the cladding alloy,

4.1.5 Cladding metal (see Section 6),

4.1.6 Base metal (see Section 6),

4.1.7 Product analysis, if required (see Section 8),

4.1.8 Mechanical Properties (see Sections 7, 13 and 14),

4.1.9 Restrictions, if required, on repair by welding (see Section 12), and

4.1.10 Additions to the specification or special requirements.

5. Materials and Manufacture

5.1 *Process:*

5.1.1 The steel shall be made by the open-hearth, electric-furnace (with separate degassing and refining optional), or basic-oxygen processes, or by secondary processes whereby steel made from these primary processes is remelted using electroslag remelting or vacuum arc remelting processes.

5.1.2 The cladding metal may be metallurgically bonded to the base metal by any method that will produce a clad steel that will conform to the requirements of this specification.

5.2 *Heat Treatment*—Unless heat treatment is required by the cladding material or base steel specification, the clad plate shall be furnished in the as-rolled condition. The purchaser and the manufacturer may agree on any other heat treatment within the base steel specification that is mutually agreeable.

6. Chemical Composition

6.1 The composite plate may conform to any desired combination cladding metal and base metal as described in 6.2 and 6.3, and as agreed upon between the purchaser and the manufacturer.

6.2 *Cladding Metal*—The nickel or nickel-base alloy cladding metal specified shall conform to the requirements as to chemical composition prescribed for the respective metal in Specifications B 127, B 162, B 168, B 333, B 409, B 424, B 443, B 463, B 575, B 582, and B 625.

6.3 *Base Metal*—The base metal may be carbon steel or low-alloy steel conforming to the ASTM specifications for steels for pressure vessels. The base metal shall conform to the chemical requirements of the specification to which it is ordered.

7. Mechanical Properties

7.1 *Tensile Requirements:*

7.1.1 The tensile properties shall be determined by a tension test of the composite plate for clad plates that meet all of the following conditions. However, if the cladding is for corrosion allowance only, the cladding may be removed before tensile testing. The tensile properties thus determined shall be not less than the minimum and not more than 5000 psi (35 MPa) over the maximum prescribed in the specification for the base steel used. All other tensile test requirements of the specification for the base steel shall be met.

7.1.1.1 The composite gage is less than or equal to $1\frac{1}{2}$ in.

7.1.1.2 The specified minimum tensile strength of the base steel is less than or equal to 70,000 psi (485 MPa).

7.1.1.3 The specified minimum yield strength of the base steel is less than or equal to 40,000 psi (275 MPa).

7.1.2 The tensile properties shall be determined by a tension test of the base steel only for clad plates that meet one of the following conditions. The properties thus determined shall meet all of the tensile test requirements for the base steel.

7.1.2.1 The composite gage is greater than $1\frac{1}{2}$ in.

7.1.2.2 The specified minimum tensile strength of the base steel is greater than 70,000 psi (485 MPa).

7.1.2.3 The specified minimum yield strength of the base steel is greater than 40,000 psi (275 MPa).

7.2 *Ductility* — Two bend tests of the composite plate shall be made, one with the cladding metal in tension and the other with the cladding metal in compression, to determine the ductility of the materials. On double-clad plates, the bend tests shall be made so that one specimen represents the cladding metal in

tension on one side while the other specimen represents the cladding metal in tension on the opposite side. Bend tests shall be made in accordance with the requirements prescribed in the specifications for the base metal.

7.3 *Bond Strength* — When required by the purchaser, three bend tests shall be made with the cladding metal in compression to determine the quality of the bond. Bends shall be made in accordance with the specifications for the base metal. At least two out of the three tests shall show not more than 50% separation on both edges of the bent portion. Greater separation shall be cause for rejection.

7.4 *Shear Strength* — As an alternative to the bend test provided in 7.3 and when required by the purchaser, the minimum shear strength of the cladding and base metals shall be 20,000 psi (140 MPa). The shear test when specified, shall be made in the manner indicated in Fig. 1.

7.5 Methods and practices relating to mechanical testing required by this specification shall be in accordance with Test Methods and Definitions A 370.

8. Product Analysis

8.1 Product analysis may be required on finished product. Chemical analysis may be accomplished by wet chemical or instrumental procedures. If wet chemical procedures are used, millings may be taken only when the composite plate thickness is sufficient to permit obtaining millings without danger of contamination from the adjacent layer. If spectrometric procedures are used, the sample shall be exposed on the center line of the cladding when there is sufficient cladding thickness available so that there is no contamination from the adjacent base metal.

8.2 If product analysis is specified by the purchaser, it shall be made on a sample taken from the finished product or a broken test specimen. For wet chemical analysis, in order to avoid contamination by the base plate metal, millings of cladding samples shall be taken from the test coupon by removal and discard of all the base metal plus 40% of the cladding thickness from the bonded side, not to exceed $^{1}/_{16}$ in. (1.598 mm). The material shall be cleaned and sufficient millings taken to represent the full cross-section of the remainder. If there is insufficient cladding thickness available to spectrographically expose on the center line of the cladding without contamination, 50% of the cladding shall be removed and the sample exposed on this surface.

8.3 The results of the product analysis shall conform to the requirements of standards referenced in Section 2.

8.4 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Definitions A 751.

8.5 Results of the product analysis shall conform to the requirements of Section 7 of Specification A 480/A 480M.

9. Dimensions, Mass, and Permissible Variations

9.1 Composite plates shall conform to the thickness and weight requirements prescribed in Table 1.

9.2 The weight and limit tolerances shall be as prescribed in Specification A 480/A 480M.

10. Thickness of Cladding Metal

10.1 The minimum thickness and tolerances on the thickness of the cladding metal shall be agreed upon between the purchaser and the manufacturer.

11. Workmanship, Finish, and Appearance

11.1 The material shall be free of injurious defects and shall have a workmanlike appearance.

11.2 Clad plates shall be furnished in the as-rolled condition, unless otherwise specified.

11.3 The clad surface may be supplied as-rolled, or as-rolled and sand blasted as specified.

12. Repair of Cladding by Welding 98

12.1 The material manufacturer may repair defects in cladding by welding provided the following requirements are met:

12.1.1 Prior approval shall be obtained from the purchaser if the repaired area exceeds 3% of the cladding surface.

12.1.2 The welding procedure and the welders or welding operators are qualified in accordance with Section IX of the ASME Code.

12.1.3 The defective area shall be removed and the area prepared for repair shall be examined by a magnetic particle method or a liquid penetrant method to ensure all defective area has been removed. Method

of test and acceptance standard shall be as agreed upon between the purchaser and the manufacturer.

12.1.4 The repair weld shall be deposited in accordance with a welding procedure and welding materials suitable for the cladding material. The surface condition of the repaired area shall be restored to a condition similar to the rest of the cladding.

12.1.5 The repaired area shall be examined by a liquid penetrant method in accordance with 12.1.3.

12.1.6 The location and extent of the weld repairs together with the repair procedure and examination results shall be transmitted as a part of the certification.

13. Number of Tests and Retests

13.1 One or more tension tests, as required by the specifications for the base metal, one face bend test (cladding metal in tension), one reverse bend test (cladding metal in compression), and, when specified, one shear test or three bond bend tests shall be made representing each plate as rolled. Each specimen shall be in the final condition of heat treatment required for the plate.

13.2 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

13.3 If any part of the fracture takes place outside of the middle half of the gage length or in a punched or scribed mark within the reduced section, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements specified, no further testing is indicated, but if the elongation is less than the minimum requirements the test shall be discarded and a retest made.

14. Test Specimens

14.1 The tension test specimens from plate shall conform to the requirements prescribed in the specifications for the base metal.

14.2 Bend test specimens shall be taken from the middle of the top of the plate as rolled, at right angles to its longitudinal axis.

14.3 When required by the purchaser, the shear test specimen shall be taken from a top or bottom corner of the plate as rolled, parallel to its longitudinal axis.

14.4 All tests shall be made on specimens in the same condition of heat treatment to which the composite plate is furnished.

14.5 When specified in the purchase order, additional test specimens representing the as-furnished composite plate shall be thermally treated to simulate a post-weld heat treatment. The temperature range, time, and cooling rates shall be specified in the purchase order. Mechanical properties in the simulated post-weld heat-treated condition shall meet the minimum requirements of the as-furnished composite plate.

14.6 For plates $1\frac{1}{2}$ in. (38.1 mm) and under in thickness tension test specimens shall be the full thickness of the material except as specified in 7.1.1 and 7.1.2, and the bend test specimen shall be full thickness of the material and shall be machined to the form and dimensions shown in Fig. 2, or may be machined with both edges parallel.

14.7 For plates over $1\frac{1}{2}$ in. in thickness tension tests shall be of the form shown in Fig. 3 and shall be of all base steel conforming to the requirements of the specification for the base steel.

14.8 For plates over $1\frac{1}{2}$ in. in thickness the bend test specimens need not be greater in thickness than $1\frac{1}{2}$ in. but shall not be less than $1\frac{1}{2}$ in. Specimens shall be of the form and dimensions shown in Fig. 2. In reducing the thickness of the specimen, both the alloy cladding and the base steel shall be machined so as to maintain the same ratio of clad metal to base steel as is maintained in the plate, except that the thickness of the clad metal need not be reduced below $\frac{1}{8}$ in. (3.17 mm).

14.9 The sides of the bend test specimen may have the corners rounded to a radius not over $^{1}/_{16}$ in. (1.58 mm) for plates $1\frac{1}{2}$ in. and under in thickness, and not over $\frac{1}{8}$ in. for plates over $1\frac{1}{2}$ in. in thickness.

14.10 Any test specimen used for the determination of the minimum thickness of cladding metal shall have distorted metal, due to burning or shearing, completely removed.

15. Inspection

15.1 The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture

prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

16. Rejection and Rehearing

16.1 Unless otherwise specified, any rejection based on tests made in accordance with Section 8, shall be reported to the manufacturer within 5 working days from the receipt of samples by the purchaser.

16.2 Material which shows injurious defects subsequent to its acceptance at the manufacturer's work will be rejected, and the manufacturer shall be notified.

16.3 Samples tested in accordance with Section 8, that represent rejected material shall be preserved for 3 weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

17. Certification

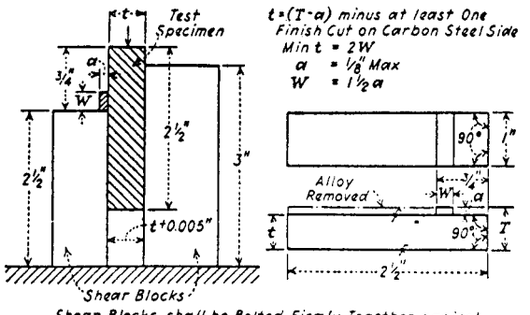
17.1 The chemical analysis of the base metal shall be certified to the purchaser by the manufacturer.

17.2 The results of the tests in Section 7, shall be reported to the purchaser or his representative.

18. Product Marking

18.1 Except as specified in 18.2, the name or brand of the manufacturer, the manufacturer's test identification number, the class of the base steel, the designation of the cladding metal, and the specified minimum tensile strength shall be legibly stamped on each finished single-clad plate in two places on the base steel side not less than 12 in. (304.8 mm) from the edges. The manufacturer's test identification number shall be legibly stamped on each test specimen.

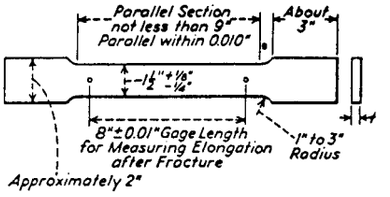
18.2 For double-clad material or for material under $\frac{1}{4}$ in. (6.35 mm) in thickness, the marking specified in 18.1 shall be legibly stenciled instead of stamped.



Metric Equivalents

in.	mm	in.	mm
0.005	0.127	1	25.4
1/8	3.17	2 1/2	64.5
3/4	19.1	3	76.2

FIG. 1 TEST SPECIMEN AND METHOD OF MAKING SHEAR TEST OF CLAD PLATE



Metric Equivalents

in.	mm	in.	mm
0.01	0.254	1 1/2	38.1
1/8	3.17	2	50.8
1/4	6.35	3	76.2
1	25.4	8	203.2

NOTE 1—When necessary, it is permissible to use a narrower specimen, but in such a case the reduced portion shall be not less than 1 in. in width.

NOTE 2—Punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the parallel section; either a set of nine punch marks 1 in. apart, or one or more sets of 8-in. punch marks may be used.

NOTE 3—The dimension *t* is the thickness of the test specimen as provided for in the applicable material specifications.

FIG. 2 STANDARD RECTANGULAR TEST SPECIMENS WITH 8 IN. GAGE LENGTH

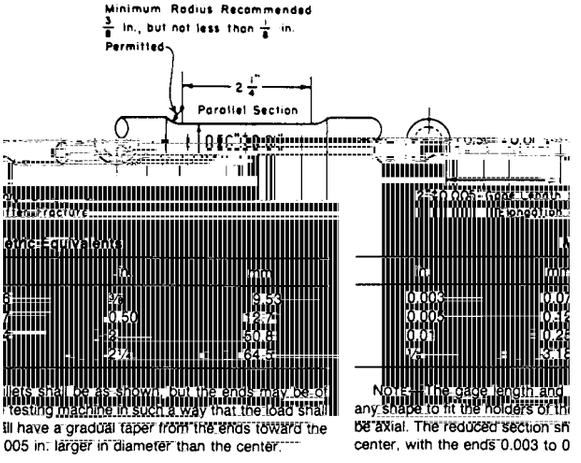

Minimum Radius Recommended 3/8 in., but not less than 1/8 in. Permitted
2 1/4"
Parallel Section
Gage Length
Fillet
Fillet
Gage Length
Reduced Section
Reduced Section
Fillet
Fillet
Gage Length

TABLE 1
PERMISSIBLE VARIATIONS IN THICKNESS AND OVERWEIGHTS OF PLATES THICKNESS[A]

Specified Thickness, in. (mm)	Permissible Excess in Average Weight per Square Foot Plates for Widths Given in inches (mm), Expressed in Percentage of Nominal Weight[D]									
	Under 48 (1219.2)	48 (1219.2) to 60 (1524.0) excl	60 (1524.0) to 72 (1828.8) excl	72 (1828.8) to 84 (2133.6) excl	84 (2133.6) to 96 (2438.4) excl	96 (2438.4) to 108 (2743.2) excl	108 (2743.2) to 120 (3048.0) excl	120 (3048.0) to 132 (3352.8) excl	132 (3352.8) to 144 (3675.6) excl	144 (3657.6) to 152 (3860.8) incl
3/16 to 1/4 (4.76 to 6.35), excl	5.25	6.00	6.75	7.50	9.00	11.50	. . .	. . .	. . .	. . .
1/4 to 5/16 (6.35 to 7.94), excl	4.50	5.25	6.00	6.75	7.50	10.50	12.00	13.00	14.25	. . .
5/16 to 3/8 (7.94 to 9.52), excl	3.75	4.50	5.25	6.00	6.75	7.50	9.00	10.00	12.75	16.00
3/8 to 7/16 (9.52 to 11.11), excl	3.50	3.75	4.50	5.25	6.00	6.75	7.50	8.50	11.25	15.00
7/16 to 1/2 (11.11 to 12.7), excl	3.00	3.50	3.75	4.50	5.25	6.00	6.75	7.50	9.75	12.75
1/2 to 5/8 (12.7 to 15.88), excl	2.75	3.00	3.50	3.75	4.50	5.25	6.00	6.75	8.25	10.50
5/8 to 3/4 (15.88 to 19.05), excl	2.25	2.75	3.00	3.50	3.75	4.50	5.00	5.50	6.25	6.75
3/4 to 1 (19.05 to 25.4), excl	2.00	2.25	2.75	3.00	3.50	3.75	4.25	4.75	5.25	6.00
1 or Over (25.4 or Over)	2.00	2.00	2.25	2.75	3.50	3.50	3.75	4.25	4.75	5.25

GENERAL NOTE: All plates shall be ordered to thickness and not to weight per square foot. No plates shall vary more than 0.01 in. (0.254 mm) under the thickness ordered, and the overweight of each lot[B] shall not exceed the amount given in the table below.[C]

NOTES:

[A] Spot grinding is permitted to remove surface imperfections not to exceed 0.01 in. (0.254 mm) under the specified thickness.

[B] The term "lot" means all of the plates of each group width and each group thickness.

[C] The weight of individual plates shall not exceed the nominal weight by more than one and one-third times the amount prescribed in the above table.

[D] Nominal weights for the composite plates shall be calculated using the following weights for the component materials:

	Density		Weight per Square Foot for Material 1 in. (25.4 mm) in Thickness, lb
	lb/in.^{3}	g/cm^3	
Steel	0.283	7.83	40.80
Nickel	0.321	8.88	46.22
Nickel-copper alloy	0.319	8.83	45.94
Nickel-chromium-iron alloy	0.307	8.49	44.21

SPECIFICATION FOR CARBON STEEL FORGINGS FOR PRESSURE VESSEL COMPONENTS 98

SA-266/SA-266M

(Identical with ASTM Specification A 266/A 266M-95) 98

1. Scope

1.1 This specification covers four classes of carbon steel forgings for boilers, pressure vessels, and associated equipment.

NOTE 1—Designations have been changed as follows:

Current	Formerly
Grade 1	Class 1
Grade 2	Class 2
Grade 3	Class 3
Grade 4	Class 4

1.2 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.3 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as the standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

98 **2.1** *ASTM Standards:*

A 275/A 275M Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions of Mechanical Testing of Steel Products

A 788 Specification for Steel Forgings, General Requirements

E 112 Methods for Determining the Average Grain Size

E 165 Practice for Liquid Penetrant Inspection Method

E 381 Method of Macroetch Testing Steel Products, Comprising Bars, Billets, Blooms, and Forgings

2.2 *Other Standard:*

ASME Boiler and Pressure Vessel Code, Section IX, Welding Qualifications

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order a detailed drawing, sketch, or written description of the forging.

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 The steel shall be made in accordance with the Melting Process Section of Specification A 788. A

sufficient discard shall be made to secure freedom from injurious pipe and undue segregation.

4.2 The material shall be forged as close as practical to the specified shape and size.

4.3 The finished product shall be a hot-worked forging defined by Specification A 788.

5. Machining

5.1 Surfaces shall be machined as designated by the purchaser. Unmachined surfaces shall be sufficiently free of scale to permit inspection.

5.2 Machining may be performed either prior to or after heat treatment at the option of the manufacturer unless specified in accordance with Supplementary Requirement S1.

6. Heat Treatment

6.1 After forging and before reheating for heat treatment, the forgings shall be cooled in such a manner as to prevent injury and to accomplish transformation.

6.2 All forgings shall be annealed, normalized, or normalized and tempered, but alternatively may be liquid quenched and tempered when mutually agreed upon between the manufacturer and the purchaser. When tempering is performed, it shall be at a subcritical temperature, but not less than 1100°F [595°C].

6.3 A multiple stage austenitizing procedure may be used whereby the forging is fully austenitized and liquid quenched, followed by reheating within the intercritical temperature range to partially reaustenitize, and again liquid quenched. On completion of the austenitizing/quenching cycles, tempering at a temperature between 1100°F [595°C] and the lower critical temperature shall follow.

NOTE 2—Although liquid quenching from the austenitizing temperatures is more effective in enhancing impact properties, air cooling from the austenitizing temperatures is also beneficial and may be used instead of the normalizing procedure in 6.2.

7. Chemical Requirements

7.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1 except the additional features of Supplementary Requirements S12 and S13 shall also apply as individually specified in the ordering information.

7.2 *Product Analysis*—The purchaser may use the product analysis provision of Specification A 788 to obtain a product analysis form a forging representing each heat or multiple heat.

8. Mechanical Properties

8.1 *General Requirements*—Except when otherwise specified in accordance with Supplementary Requirement S2, the material shall conform to the requirements for mechanical properties prescribed in Table 2 when tested in accordance with the latest issue of Test Methods and Definitions A 370. The largest obtainable tension test specimen as specified in Test Methods and Definitions A 370 shall be used.

8.1.1 Except when otherwise specified in accordance with Supplementary Requirement S2, the longitudinal axis of the specimens shall be parallel to the direction of major working of the forging. For upset-disc forgings, the longitudinal axis of the test specimen shall be in the tangential direction.

8.1.1.1 The longitudinal axis of the specimen shall be located midway between the parallel surfaces of the test extension if added to the periphery of disks or midway between the center and surface of solid forgings. For hollow forgings, the longitudinal axis of the specimens shall be located midway between the center and outer surfaces of the wall. When separately forged test blocks are employed as defined in 8.1.3, the tension test specimens shall be taken from a location which represents the midwall of the heaviest section of the production forgings. When specimens are required from opposite ends, they shall be taken from the diagonal corners of an axial plane.

8.1.2 Except as specified herein, tests for acceptance shall be made after heat treatment has been completed. When the ends of cylindrical forgings are closed in by reforging, the cylindrical forgings may be annealed, normalized, or normalized and tempered and tested prior to reforging. After reforging, the entire forging shall be reheat treated in the same manner and at the same temperature range as employed when the forging was heat treated prior to certification testing.

8.1.3 When mutually agreed upon between manufacturer and purchaser, test specimens may be machined from a specially forged block suitably worked and heat treated with the production forgings. Such a special block shall be obtained from an ingot, slab, or billet from the same heat used to make the forgings it represents. This block shall receive essentially the same

type of hot working and forging reduction as the production forgings; however, a longitudinally forged bar with dimensions not less than *T* by *T* by 3*T* may be used to represent a ring forging. The dimension *T* shall be representative of the heaviest effective cross section of the forging. For quenched and tempered forgings for which tests are required at both ends by 8.2.2.3 and 8.2.2.4, separately forged test blocks are not allowed.

NOTE 3—In using separately forged test blocks, attention is drawn to effect of mass differences between the production forgings and the test blocks.

8.2 *Specific Requirements*—The number and location of tests are based on forging length, weight, and heat treatment, and shall be as prescribed below. The length and weight to be used for this purpose shall be the shipped length and weight of forgings produced individually or the aggregate shipped length and weight of all pieces cut from a multiple forging.

8.2.1 *Annealed, Normalized, or Normalized and Tempered Steel Forgings:*

8.2.1.1 For forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, one tension test shall be taken from one forging per heat in each heat-treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat-treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8-h period.

8.2.1.2 For forgings and forged bars weighing over 5000 lb [2250 kg] at the time of heat treatment, one tension test shall be taken from each forging.

8.2.2 *Quenched and Tempered Forgings:*

8.2.2.1 For quenched and tempered forgings weighing 5000 lb [2250 kg] or less at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from one forging per heat in each heat-treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature controls and equipped with recording pyrometers so that complete heat-treatment records are available, a tempering charge may be considered as any continuous run not exceeding an 8-h period.

8.2.2.2 For quenched and tempered forgings and forged bars weighing over 5000 lb [2250 kg] to 10 000 lb [4500 kg] at the time of heat treatment, but not exceeding 12 ft [3.7 m] in length, one tension test shall be taken from each forging.

8.2.2.3 For quenched and tempered forgings and forged bars that exceed 12 ft [3.7 m] in length, one tension test shall be taken from each end of each forging.

8.2.2.4 For quenched and tempered forgings and forged bars weighing more than 10 000 lb [4500 kg] at the time of heat treatment, two tension tests shall be taken from each forging. These shall be offset 180° from each other except that when the length excluding test prolongations exceeds three times the diameter or equivalent thickness, one test shall be taken from each end of the forging and shall be taken from each end of the forging and shall be oriented 180° apart. In the case of circular forgings, the diameter is the largest diameter of the forging excluding flanges. For other configurations, the term equivalent thickness is the maximum diagonal or major axis of the cross section.

9. Repair Welding

9.1 Repair welding of forgings is permissible only at the option of the purchaser. If repair welding is performed, welders and weld procedures shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10. Certification

10.1 In addition to the mandatory certification requirements of Specification A 788, the heat treatment cycle data shall be included.

11. Product Marking

11.1 Each forging shall be identified in accordance with the Marking Section of Specification A 788. In addition, the forging shall be marked following the class designation by the letter “A” for annealed, “N” for normalized, “NT” for normalized and tempered and “S” for liquid quenched and tempered, as applicable.

12. Keywords

12.1 pressure vessel service; steel forgings—carbon 98

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %		
	Grades 1 and 2	Grade 3	Grade 4
Carbon, max	0.35	0.45	0.30
Manganese	0.40–1.05	0.50–0.90	0.80–1.35
Phosphorus, max	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025
Silicon	0.15–0.35	0.35 max	0.15–0.35

TABLE 2
TENSILE REQUIREMENTS

	Grade 1	Grades 2 and 4	Grade 3
Tensile strength, min, ksi [MPa]	60–85 [415–585]	70–95 [485–655]	75–100 [515–690]
Yield strength (0.2% offset), min, ksi [MPa]	30 [205]	36 [250]	37.5 [260]
Elongation in 2 in. or 50 mm, min, %	23	20	19
Reduction of area, min, %	38	33	30

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Rough Turning and Boring

S1.1 The position of the rough turning and boring in the sequence of manufacturing operations shall be as specified by the purchaser.

S2. Alternative Tension Test Orientation

S2.1 In lieu of the requirements of Section 8, the longitudinal axis of the test specimens shall be transverse to the direction of major working of the forging. The results shall conform with requirements of Table 3 with the exception of the ductility limits that shall be as follows:

Class	1	2 and 4	3
Elongation in 2 in. [50 mm], min, %	20	19	18
Reducation of area, min, %	30	25	25

S3. Hydrostatic Test

S3.1 A hydrostatic pressure test shall be applied. The details of the test, including its position in the sequence of manufacturing operations, shall be specified.

S4. Magnetic Particle Examination

S4.1 All accessible surfaces of the finished forging shall be examined by a magnetic particle method. The method shall be in accordance with Test Method A 275/A 275M. Acceptance limits shall be as agreed upon between the manufacturer and the purchaser.

S5. Liquid Penetrant Examination

S5.1 After forgings have been heat treated by liquid quenching and tempering, all accessible surfaces shall be inspected for quench cracks by the liquid penetrant method in accordance with Practice E 165 as an alternative to magnetic particle examination.

S6. Macroetch Test

S6.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted in accordance with Method E 381. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S7. Product Analysis

S7.1 A product analysis in accordance with Section 7 shall be made from one randomly selected forging representing each size and shape of forging on the order. If the analysis fails to comply, each forging shall be checked or the lot rejected. All results shall be reported to the purchaser.

S8. Specimen Location on Forged Hubs

S8.1 Forged hubs to be butt-welded to shells shall be forged in such a manner as to provide in the hub the full minimum tensile strength and elongation specified for the material, in a direction parallel to the axis of the vessel. A tension specimen (subsize if necessary) shall be taken in this direction and as close to the finished hub outside diameter as practical.

S9. Hardness

S9.1 The purchaser may check the Brinell hardness of the forging at any location on the surface of the forging, and the hardness shall be within the following limits:

Class	Brinell Hardness Limits
1	121 to 170
2 and 4	137 to 197
3	156 to 207

S10. Grain Size

S10.1 The austenitic grain size of the steel shall be 1 to 5 as determined using Test Methods E 112.

S11. Restriction on Residual Elements (Applicable to Heat Analysis)

S11.1 Nickel, chromium, and molybdenum shall be determined and shall not exceed the following limits:

Nickel	0.25%
Chromium	0.20% max
Molybdenum	0.08% max

S12. Restriction on Carbon (Applicable to Class I)

S12.1 The carbon content shall be 0.30% max.

S13. Impact Tests

S13.1 Charpy impact tests shall be made. The number and location of the tests, minimum properties, and test temperatures shall be specified.

S13.2 The specimens shall be machined and tested in accordance with Test Methods and Definitions A 370.

S13.3 Retests may be conducted in accordance with Section 10 of Specification A 788.

S14. Individual Forging

S14.1 Forgings, whether identical or not, shall be produced individually. They shall not be forged in multiples and separated prior to or after heat treatment.

S14.2 The shape and size of individual forgings shall be agreed upon between the manufacturer and the purchaser by means of a forging drawing or the purchase order.

S15. Carbon Equivalancy

S15.1 The heat analysis including the residual element restrictions of S1 in Specification A 788 shall be limited such that the carbon equivalent shall not exceed 0.45 for Grade 1 or 0.50 for Grades 2 or 4 when calculated according to the following formula:

$$CE = \%\,C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Ni + \%Cu}{15}$$

SPECIFICATION FOR SEAMLESS AND WELDED FERRITIC AND MARTENSITIC STAINLESS STEEL TUBING FOR GENERAL SERVICE

SA-268/SA-268M

(Identical with ASTM Specification A 268/A 268M-94.)

1. Scope

1.1. This specification covers a number of grades of nominal-wall-thickness, stainless steel tubing for general corrosion-resisting and high-temperature service. Most of these grades are commonly known as the "straight-chromium" types and are characterized by being ferromagnetic. Two of these grades, TP410 and UNS S41500 (Table 1), are amenable to hardening by heat treatment, and the high-chromium, ferritic alloys are sensitive to notch-brittleness on slow cooling to ordinary temperatures. These features should be recognized in the use of these materials. Grade TP439 is used primarily for hot-water tank service and does not require post-weld heat treatment to prevent attack of the heat affected zone.

NOTE 1—TP329 (S32900) formerly in this specification, has been transferred to A 789/A 789M and A 790/A 790M.

1.2 An optional supplementary requirement is provided, and when desired, shall be so stated in the order.

NOTE 2—For tubing smaller than $\frac{1}{2}$ in. [12.7 mm] in outside diameter, the elongation values given for strip specimens in Table 2 shall apply. Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in outside diameter or with walls thinner than 0.015 in. [0.4 mm].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A 789/A 789M Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service

A 790/A 790M Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of Specification A 450/A 450M unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to described the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (seamless or welded tubes),

4.1.3 Grade (Table 1),

4.1.4 Size (outside diameter and nominal wall thickness),

4.1.5 Length (specific or random),

4.1.6 Optional requirements (hydrostatic or electric test, 13.7),

4.1.7 Test report required (Certification Section of Specification A 450/A 450M),

4.1.8 Specification designation, and

4.1.9 Special requirements.

5. Manufacture

5.1 The tubes shall be made by the seamless or welded process with no filler metal added.

6. Heat Treatment

6.1 As a final heat treatment, tubes shall be reheated to a temperature of 1200°F [650°C] or higher and cooled (as appropriate for the grade) to meet the requirements of this specification.

6.2 The martensitic grade UNS S41500 shall be reheated to a temperature of 950°F [510°C] or higher and cooled as appropriate to meet the requirements of this specification.

7. Chemical Composition

7.1 The steel shall conform to the chemical requirements prescribed in Table 1.

8. Product Analysis

8.1 An analysis of either one billet or one length of flat-rolled stock or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

8.2 The product analysis tolerance of the Chemical Requirements Table of A 480/A 480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04% or less.

8.3 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 3) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 3 — For flange and flaring requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

NOTE 4 — For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

9. Tensile Requirements

9.1 The material shall conform to the tensile properties prescribed in Table 3.

10. Hardness Requirements

10.1 The tubes shall have a hardness number not to exceed those prescribed in Table 4.

11. Permissible Variations in Dimensions

11.1 Variations in outside diameter, wall thickness, and length from those specified shall not exceed the amounts prescribed in Table 5.

11.2 The permissible variations in outside diameter given in Table 5 are not sufficient to provide for ovality in thin-walled tubes, as defined in the Table. In such tubes, the maximum and minimum diameters at any cross section shall deviate from the nominal diameter by no more than twice the permissible variation in outside diameter given in Table 5; however, the mean diameter at that cross section must still be within the given permissible variation.

12. Surface Condition

12.1 All tubes shall be free of excessive mill scale, suitable for inspection. A slight amount of oxidation will not be considered as scale. Any special finish requirements shall be subject to agreement between the manufacturer and the purchaser.

13. Mechanical Tests Required

13.1 *Tension Tests* — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 4).

13.2 *Flaring Test (For Seamless Tubes)* — One test shall be made on specimens from one end of one tube from each lot (Note 3) of finished tubes. The minimum expansion of the inside diameter shall be 10%. For tubes over 8 in. [203.2 mm] in outside diameter, or tubes with wall thickness $\frac{3}{8}$ in. [9.52 mm] and over, the flattening test may be performed instead of the flaring test unless the flaring test is specified in the purchase order.

13.3 *Flange Test (For Welded Tubes)* — One test shall be made on specimens from one end of one tube from each lot (Note 3) of finished tubes. For tubes over 8 in. [203.2 mm] in outside diameter, or tubes with wall thickness $\frac{3}{8}$ in. [9.52 mm] and over, the flattening test may be performed instead of the flange test unless the flange test is specified in the purchase order.

13.4 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 4).

13.5 When more than one heat is involved, the tension, flaring, flanging, and hardness test requirements shall apply to each heat.

13.6 *Reverse Flattening Test* — For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

13.7 *Hydrostatic or Nondestructive Electric Test* — Each welded tube shall be subjected to either the hydrostatic or nondestructive electric test. The purchaser may specify which test is to be used. Each seamless tube shall be subjected to the hydrostatic test, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

14. Product Marking

14.1 In addition to the marking described in Specification A 450/A 450M, the marking shall indicate whether the tubing is seamless or welded.

15. Keywords

15.1 ferritic stainless steel; seamless steel tube; stainless steel tube; steel tube; welded steel tube

TABLE 1
CHEMICAL REQUIREMENTS

NOTE — TP329 (S32900), formerly part of this specification, has been transferred to A789/A789M and A790/A790M.

Grade	TP405	TP410	TP429	TP430	TP443	TP446-1	TP446-2[A]	...	TP409
UNS Designation[B]	S40500	S41000	S42900	S43000	S44300	S44600	S44600	S40800	S40900
Element	Composition, %								
C, max	0.08	0.15	0.12	0.12	0.20	0.20	0.12	0.08	0.08
Mn, max	1.00	1.00	1.00	1.00	1.00	1.50	1.50	1.00	1.00
P, max	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.045	0.045
S, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.045	0.045
Si, max	0.75	0.75	0.75	0.75	0.75	0.75	0.75	1.00	1.00
Ni	0.50 max	0.50 max	0.50 max	0.50 max	0.50 max	0.50 max	0.50 max	0.80 max	0.50 max
Cr	11.5–13.5	11.5–13.5	14.0–16.0	16.0–18.0	18.0–23.0	23.0–30.0	23.0–30.0	11.5–13.0	10.50–11.75
Mo	...	...	...	...	...	...	...	...	...
Al	0.10–0.30	...	...	...	...	...	...	...	...
Cu	...	...	...	...	0.90–1.25	...	...	...	...
N	...	...	...	...	...	0.10–0.25	0.10–0.25	...	...
Ti	...	...	...	...	...	...	...	12 × C min; 1.10 max	6 × C min; 0.75 max

Grade	TP 439	...	TP430 Ti	TP XM-27	TP XM-33[D]	18Cr-2Mo	29-4	29-4-2	26-3-3	25-4-4	...[C]	...
UNS Designation	S43035	S41500[E]	S43036	S44627	S44626	S44400	S44700	S44800	S44660	S44635	S44735	S32803
Element	Composition, %											
C, max	0.07	0.05	0.10	0.01[D]	0.06	0.025	0.010	0.010	0.030	0.025	0.030	0.015[H]
Mn, max	1.00	0.5–1.0	1.00	0.40	0.75	1.00	0.30	0.30	1.00	1.00	1.00	0.5
P, max	0.040	0.03	0.040	0.02	0.040	0.040	0.025	0.025	0.040	0.040	0.040	0.020
S, max	0.030	0.03	0.030	0.02	0.020	0.030	0.020	0.020	0.030	0.030	0.030	0.005
Si, max	1.00	0.60	1.00	0.40	0.75	1.00	0.20	0.20	1.00	0.75	1.00	0.50
Ni	0.50 max	3.5–5.5	0.75 max	0.5[F] max	0.50 max	1.00 max	0.15 max	2.0–2.5	1.0–3.50	3.5–4.5	1.00 max	3.0–4.0
Cr	17.00–19.00	11.5–14.0	16.00–19.50	25.0–27.5	25.0–27.0	17.5–19.5	28.0–30.0	28.0–30.0	25.0–28.0	24.5–26.0	28.00–30.00	28.0–29.0
Mo	...	0.5–1.0	...	0.75–1.50	0.75–1.50	1.75–2.50	3.5–4.2	3.5–4.2	3.0–4.0	3.5–4.5	3.60–4.20	1.8–2.5
Al, max	0.15	...	...	...	...	...	...	...	...	...	...	...
Cu, max	...	...	...	0.2	0.20	...	0.15	0.15	...	...	...	...
N, max	0.04	...	...	0.015	0.040	0.035	0.020[G]	0.020[G]	0.040	0.035	0.045	0.020
Ti	0.20 + 4 (C + N) min; 1.10 max	...	5 × C min; 0.75 max	...	7 × (C + N) but no less than 0.20 min; 1.00 max	(Ti + Cb) 0.20 + 4 (C + N) min; 0.80 max	...	...	(Ti + Cb) = 0.20–1.00 and 6 × C + N) min	(Ti + Cb) = 0.20 + 4 (C + N) min to 0.80 max	(Ti + Cb) 0.20 1.00 with 6 (C + N) min	...
Cb	...	...	...	0.05–0.20	...	...	...	...	...	...	...	0.15–0.50[I]

[A] TP446-2 is a lower carbon version of TP446-1 that has a lower tensile strength but improved ductility and fracture toughness.
[B] New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).
[C] When intergranular corrosion testing is specified, the test will be Practices A 763, using samples prepared as agreed upon between the seller and the purchaser.
[D] For small diameter or thin walls, or both, tubing, where many drawing passes are required, a carbon maximum of 0.015% is necessary. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.040 in. [1 mm] in minimum wall thickness).
[E] Plate version of CA6NM.
[F] Nickel plus copper.
[G] Carbon plus nitrogen = 0.025% max.
[H] Carbon plus nitrogen = 0.30 max.
[I] Cb/(C + N) = 12 min.

TABLE 2
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

NOTE—TP329 (S32900), formerly part of this specification, has been transferred to A 789/A 789M and A 790/A 790M.

Grade and UNS Designation	Tensile strength, min, ksi [MPa]	Yield strength, min, ksi [MPa]	Elongation[A] in 2 in. or 50 mm, min, %
TP405 S40500	60 [415]	30 [205]	20
. . . S40800	55 [380]	30 [205]	20
TP410 S41000	60 [415]	30 [215]	20
TP429, TP430, and TP430 Ti S429000, S43000, and S43036	60 [415]	35 [240]	20
TP443 S44300	70 [485]	40 [275]	20
TP446-1 S44600	70 [485]	40 [275]	18
TP446-2 S44600	65 [450]	40 [275]	20
TP409 S40900	55 [380]	30 [205]	20
TP439 S43035	60 [415]	30 [205]	20
. . . S41500	115 [795]	90 [620]	15
TPXM-27 S44627	65 [450]	40 [275]	20
TPXM-33 S44626	68 [470]	45 [310]	20
18Cr-2Mo S44400	60 [415]	40 [275]	20
29-4 and 29-4-2 S44700 and S44800	80 [550]	60 [415]	20
26-3-3 S44660	85 [585]	65 [450]	20
25-4-4 S44635	90 [620]	75 [515]	20
. . . S44735	75 [515]	60 [415]	18
28-2-3.5 S32803	87 [600]	72 [500]	16

TABLE 3 (CONT'D)
TENSILE REQUIREMENTS

Wall Thickness		Elongation in 2 in. or 50 mm, min, %		
in.	mm	TP446-1 and S44735	S41500	All Other Grades
5/16 [0.312]	8	18	15	20
9/32 [0.281]	7.2	17	14	19
1/4 [0.250]	6.4	16	14	18
7/32 [0.219]	5.6	15	13	17
3/16 [0.188]	4.8	14	12	16
5/32 [0.156]	4	13	11	15
1/8 [0.125]	3.2	13	11	14
3/32 [0.094]	2.4	12	10	13
1/16 [0.062]	1.6	11	9	12
0.062–0.035, excl	1.6–0.9	10	8	12
0.035–0.022, excl	0.9–0.6	10	8	11
0.022–0.015, incl	0.6–0.4	10	8	11

NOTES — The above table gives the computed minimum values for each 1/32 in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

Grade	Equation
TP446-1 and S44735	$E = 28.8t + 9.00$ [$E = 1.13t + 9.00$]
S41500	$E = 24t + 7.5$
All other grades	$E = 32t + 10.00$ [$E = 1.25t + 10.00$]

where:
E = Elongation in 2 in. or 50 mm, %, and
t = actual thickness of specimen, in. [mm].

[A] For longitudinal strip tests a deduction of 0.90% for TP446-1 and S44735 and 1.00% for all other grades shall be made from the basic minimum elongation for each 1/32 in. [0.8 mm] decrease in wall thickness below 5/16 in. [8 mm]. The following table gives the computed minimum values.
[B] Calculated elongation requirements shall be rounded to the nearest whole number.

TABLE 4
HARDNESS REQUIREMENTS

NOTE — TP329 (S32900), formerly part of this specification, has been transferred to A 789/A 789M and A790/A 790M.

Grade	UNS Designation	Brinell Hardness, max	Rockwell Hardness, B Scale, max
TP405	S40500	207	95
. . .	S40800	207	95
TP410	S41000	207	95
TP429, TP430, and TP430 TI	S42900, S43000, and S43036	190	90
TP443	S44300	207	95
TP446-1 and TP446-2	S44600	207	95
TP409	S40900	207	95
TP439	S43055	190	90
. . .	S41500	295[A]	32
TPXM-33 and TPXM-27	S44626 and S44627	241	100
18Cr-2Mo	S44400	217	95
29-4 and 29-4-2	S44700 and S44800	207	100
26-3-3	S44660	265	25[A]
25-4-4	S44635	270	27[A]
. . .	S44735	. . .	100
28-2-3.5	S32803	240	100

[A] Rockwell hardness, C scale.

TABLE 5
PERMISSIBLE VARIATIONS IN DIMENSIONS

Group	Size, Outside Diameter, in. [mm]	Permissible Variations in Outside Diameter, in. [mm]	Permissible Variations in Wall Thickness, %[C]	Permissible Variations in Cut Length, in.[A] [mm]		Thin Walled Tubes[B]
				Over	Under	
1	Up to 1/2 [12.7], excl	±0.005 [0.13]	±15	1/8 [3]	0	. . .
2	1/2 to 1 1/2 [12.7 to 38.1], excl	±0.005 [0.13]	±10	1/8 [3]	0	less than 0.065 in. [1.6 mm] nominal
3	1 1/2 to 3 1/2 [38.1 to 88.9], excl	±0.010 [0.25]	±10	3/16 [5]	0	less than 0.095 in. [2.4 mm] nominal
4	3 1/2 to 5 1/2 [88.9 to 139.7], excl	±0.015 [0.38]	±10	3/16 [5]	0	less than 0.150 in. [3.8 mm] nominal
5	5 1/2 to 8 [139.7 to 203.2], incl	±0.030 [0.76]	±10	3/16 [5]	0	less than 0.150 in. [3.8 mm] nominal

[A] These tolerances apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over tolerances shall be increased by 1/8 in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft, or 1/2 in. [13 mm], whichever is lesser.
[B] Ovality provisions of 12.2 apply.
[C] When tubes as ordered require wall thicknesses 3/4 in. [19 mm] or over, or an inside diameter 60% or less of the outside diameter, a wider variation in wall thickness is required. On such sizes a variation in wall thickness of 12.5 % over or under will be permitted.
For tubes less than 1/2 in. [12.7 mm] in inside diameter which cannot be successfully drawn over a mandrel, the wall thickness may vary ±15 % from that specified.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Air-Underwater Pressure Test

S1.1 Each tube, with internal surface clean and dry, shall be internally pressurized to 150 psi [1000 kPa] minimum with clean and dry compressed air while being submerged in clear water.

S1.2 The tube shall be well-lighted, preferably by underwater illumination.

S1.3 Any evidence of air leakage of the pneumatic couplings shall be corrected prior to testing.

S1.4 After holding the pressure for not less than 5 s after the surface of the water has become calm, an inspection shall be made of the entire external surface of the tube.

S1.5 If any tube leaks during the air-underwater test, it shall be rejected. Any leaking areas may be cut out and the tube retested as above.

SPECIFICATION FOR MAGNETIC PARTICLE EXAMINATION OF STEEL FORGINGS

SA-275/SA-275M

(Identical with ASTM Specification A 275/A275M-96 except for editorial differences in 15.1.) 98

1. Scope

1.1 This test method provides a procedure for magnetic particle examination of steel forgings. The procedure will produce consistent results upon which acceptance standards can be based. This standard does not contain acceptance standards or recommended quality levels.

1.2 Only direct current or rectified alternating (full or half wave) current shall be used as the electric power source for any of the magnetizing methods. Alternating current is not permitted because its capability to detect subsurface discontinuities is very limited and therefore unsuitable.

NOTE 1—Guide E 709 may be utilized for magnetic particle examination in the field for machinery components originally manufactured from steel forgings.

1.3 The values stated in either inch-pound or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 This specification and the applicable material specifications are expressed both in inch-pound and SI units. However, unless the order specifies the applicable "M" specification designation [SI units], the material shall be furnished to inch-pound units.

1.5 The minimum requirements for magnetic particle examination shall conform to practice standards of Practice E 1444. If the requirements of this test method are in conflict with the requirements of Practice E 1444, the requirements of this test method shall prevail.

1.6 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standard:*

E 709 Practice for Magnetic Particle Examination

E 1444 Practice for Magnetic Particle Examination

2.2 *Other Document:*

Recommended Practice No. SNT-TC-1A, Supplement B-Magnetic Particle Method

3. Terminology

3.1 *Definitions:*

3.1.1 *indication*—the visual magnetic particle buildup resulting from leakage fields in the magnetic field.

3.1.2 *linear indication*—an indication in which the length is at least three times the width. The minimum length of indications to be considered linear shall be $^1/_{16}$ in. [1.6 mm].

3.1.3 *magnetic flux*—the product of the magnetic induction and the area of a surface (or cross section) when the magnetic induction is uniformly distributed and normal to the plane of the surface. The concept that the magnetic field is flowing along the lines of force suggests that these lines are therefore flux lines, and they are called magnetic flux.

3.1.4 *magnetic particle method of examination*—a method for detecting discontinuities on or near the surface in suitably magnetized materials, which employs finely divided magnetic particles that tend to congregate in regions of leakage fields.

3.1.5 *nonrelevant indication*—indications produced by leakage fields. However, the conditions causing them are present by design or accident, or other features of the part having no relation to the damaging flaws being sought. The term signifies that such an indication has no relation to the discontinuities that might constitute defects.

4. Basis of Application

4.1 When in accordance with the requirements of the inquiry, contract, order, or specifications, forgings are furnished subject to magnetic particle examination, the manufacturer and the purchaser shall be in agreement concerning the following:

4.1.1 The locations on the forgings that are to be subjected to magnetic particle examination.

4.1.2 The type, size, number, location, and orientation of indications that are to be considered injurious.

4.1.3 The method of application of magnetic particles, demagnetization requirements and magnetic field strengths.

4.2 In cases where large undercuts in the forgings are to be taken by the purchaser, the manufacturer shall be given the privilege (when the design permits) of machining slots or grooves in the rough-machined forging to explore the internal conditions prior to shipping.

4.3 Acceptance standards.

5. Personnel Requirements

5.1 Personnel performing the examination in accordance with this test method shall be qualified and certified in accordance with a written procedure conforming to Recommended Practice No. SNT-TC-1A or another national standard that is acceptable to both the purchaser and the supplier.

6. Stage of Inspection

6.1 Unless otherwise specified by the purchaser, acceptance inspection shall be performed on a forging in the final machined surface condition and final thermally treated condition or within 0.030 in. [0.8 mm] of the final machined surface condition.

7. Magnetizing Apparatus

7.1 Rectified alternating (full or half wave) or direct-current electric power sources may be used. When current is passed through the part itself, the equipment shall consist of contacting or clamping elements with sufficient surface area and clamping pressure to allow the required current to flow without damaging (burning) the part being examined.

7.2 Portable electromagnetic (ac-dc) yokes may be used in the dc mode as a magnetizing apparatus, provided the sensitivity to detect crack-like defects is demonstrated to be at least equivalent to that of the direct-magnetization method.

8. Magnetic Particles

8.1 The inspection medium shall consist of finely divided ferromagnetic particles, which may be suspended in a suitable liquid medium, or used in dry powder form.

8.2 The size and shape of the particles, and their magnetic properties, both individually and collectively, are important (see Section 11).

9. Surface Preparation

9.1 The sensitivity of the magnetic particle examination will depend to a considerable extent upon the condition of the surface being tested. Defects may be satisfactorily revealed on shot-blasted or otherwise cleaned forged surfaces, or on surfaces having small amounts of heat-treating scale without any special surface preparation; however, loose scale must be removed. To reveal fine defects, the surfaces to be inspected should be smooth machined to at least a 250 μin. [6.35 μm] finish.

9.2 The surfaces shall be free of grease, oils, or other substances to which the particles may adhere.

9.3 Rough surfaces hamper the mobility of magnetic powders due to mechanical trapping which in turn produces false indications. Such areas should be surface ground. If grinding is impractical, a paper tape overlay (as described in 14.1.1.2) may eliminate the problem.

10. Methods of Magnetization

10.1 The forging may be magnetized either by passing current through the piece or by inducing a magnetic field by means of a central conductor by coils.

10.1.1 *Continuous Method*—In the continuous method, the inspection medium is applied to the surface under inspection while the current is still flowing. The current source generates high amperage current in pulses of up to 1-s duration. The duration of this flow shall allow at least three pulses of current or in the case where machines supply continuous current flow a minimum shot of $\frac{1}{5}$ to $\frac{1}{2}$-s duration should be applied.

10.1.2 *Surge Method*—In the surge method a high-magnetizing force is applied and then reduced to a lower continuous value, which is maintained during application of the inspection medium.

10.1.3 *Residual Method*—In the residual method the inspection medium is applied to the surface under inspection after the magnetizing current has ceased to flow. The effectiveness of this method depends upon the strength of the magnetizing force and the retentivity of the piece, which in turn depends upon such factors as chemical composition, heat treatment, etc. The residual method is not acceptable for forgings being inspected to comply with some regulatory bodies; it shall be used, therefore, only when approved by the purchaser.

10.2 At least two separate examinations shall be carried out on each area. The second examination shall be with the lines of magnetic flux approximately perpendicular to those used for the first examination in that area. A different means of magnetizing may be used for the second examination. Magnetizing in more than one direction cannot be accomplished simultaneously.

NOTE 2—An exception to the above rule is overall sequential multivector magnetization whereby several magnetizing circuits are provided for sequentially magnetizing a part in multiple directions depending upon the locations of the current connectors. By this technique, flaws of any orientation can be detected with a single application of magnetic particles.

10.3 The two general types of magnetization with regard to direction are longitudinal and circular, as follows:

10.3.1 *Longitudinal*—When a forging is magnetized longitudinally, the magnetic flux lines are usually parallel to the axis of the piece. A longitudinally magnetized piece always has definite poles readily detectable by compass or magnetometer. Longitudinal magnetization is usually accomplished by placing the forging within a solenoid, often formed by wrapping cable around the piece (Fig. 1). For special applications, magnetic yokes can be used (Fig. 2) when requirements of 7.2 are met.

10.3.2 *Circular*—Circular magnetization is obtained by passing a current directly through the piece (Fig. 3), or induced through a conductor (Fig. 4), or conductors threaded (Fig. 5) through an opening in the piece. Localized circular magnetization may be obtained by passing current through the local areas by use of prod-type contacts (Fig. 6).

10.4 The magnetic field is confined almost entirely to the piece and there may be no external manifestation of the magnetized condition. Indications will appear strongest in the direction perpendicular to the direction of the magnetic field.

10.5 *Field Strength*—The minimum field strength that will reveal and permit classification of all objectionable defects shall be used. The maximum field strengths practical are the ones just below the point at which excessive adherence of the particles begins to occur over the surface being inspected.

10.5.1 *Coil Magnetization*—When coil magnetization is used, the magnetic field strength is directly proportional to the current (ampere-turns if a coil or solenoid is used) and inversely proportional to the thickness of the section being inspected.

10.5.1.1 *Longitudinal Magnetization*—For encircling coils (Fig. 1), the turns of the coil shall be kept closely together. The field strength decreases as distance from the coil increases and long parts must be magnetized in sections. If the area to be inspected extends beyond 6 in. [150 mm] on either side of the coils, the adequacy of the field shall be demonstrated by the use of field indicators (see 10.5.6).

(*1*) *Small Forgings*—Magnetizing force shall be 35 000 ampere-turns divided by the sum of 2 plus the "length over diameter" ratio of the test part. For example, a part 10 in. [250 mm] long by 2 in. [50 mm] in outside diameter has an *L/D* ratio of 5. Therefore, $35\,000/(2 + 5) = 5000$ ampere-turns; if a 5-turn coil is used, the current required is 5000/5 or 1000 A. This formula provides an adequate field strength on small parts having an *L/D* ratio of 4 or greater. For parts having a smaller *L/D* ratio, adequate field strengths shall be demonstrated by the use of a field indicator (see 10.5.6). The graph in Fig. 7 may be used to determine the ampere-turns required for each *L/D* relationship.

(*2*) *Large Forgings*—For large forgings the magnetizing force shall be in the range from 1200 to 4500

ampere-turns. A field indicator (see 10.5.6) shall be used to demonstrate the presence of an adequate field strength over the area to be inspected.

10.5.1.2 *Circular Magnetization* (Fig. 5)—For circular magnetization with through coils, use the current with amperage as specified in 10.5.2 divided by the number turns in the coil.

10.5.2 *Direct Magnetization*—When current is passed directly through the part to be examined, the current shall be between 100 and 900 A [4 and 35 A per mm] per in. of diameter or cross section (per in. or mm of greatest width in a plane at right angles to current flow). For hollow parts this would be wall thickness when cables are clamped to the wall. Suggested current for diameters or sections up to 5 in. [125 mm] are 600 to 900 A/in. [25 to 35 A per mm]; for diameters or sections between 5 and 10 in. [125 to 250 mm], 400 to 600 A/in. [15 to 25 A per mm]; and 100 to 400 A/in. [4 to 15 A per mm] for outside diameters or sections over 10 in. [250 mm]. If it is not practical to obtain these current levels for diameters over 10 in. [250 mm], the presence of an adequate field strength shall be demonstrated using a field indicator. In all other instances the adequacy of the magnetizing force shall be demonstrated by means of a field indicator (see 10.5.6). When large parts have been examined by clamping contacts to the wall thickness the adequacy of the field in the circumferential direction shall also be determined by the field indicator.

10.5.3 *Prod Magnetization*—When prods are used to circularly magnetize a local area, the field strength is directly proportional to the amperage used but also varies with the prod spacing and thickness of section being inspected.

10.5.3.1 A magnetizing force of 75 to 100 A per linear in. [3 to 4 A per mm] of prod spacing shall be used for material under $\frac{3}{4}$ in. [20 mm] thick, and 100 to 125 A per linear in. [4 to 5 A per mm] of prod spacing shall be used for material $\frac{3}{4}$ in. [20 mm] and over in thickness.

10.5.3.2 Prod spacing shall be a maximum of 8 in. [200 mm]. Prod spacing less than 3 in. [75 mm] usually is not feasible due to banding of the particles around the prods. Care shall be taken to prevent local overheating or burning of the surface being examined. Steel- or aluminum-tipped prods or copper-brush type prods rather than solid copper-tipped prods are recommended where the magnetizing voltage is over 25 V open circuit (bad contact) in order to avoid copper penetration. Permanent magnetic leeches may be used as a pair or in conjunction with a prod. Leeches should no be used in excess of 1500 A because loss of magnetization occurs.

10.5.3.3 A remote control switch, which may be built into the prod handles, shall be provided to permit the current to be turned on after the prods have been properly positioned and to turn it off before the prods are removed in order to prevent arcing.

10.5.3.4 *Examination Coverage*—Examinations shall be conducted with sufficient overlap to assure 100% coverage at the established sensitivity.

10.5.3.5 *Direction of Magnetization*—At least two separate examinations shall be carried out on each area. The prods shall be placed so that the lines of flux during one examination are approximately perpendicular to the lines of flux during the order.

10.5.4 Indirect circular magnetization of the bores of shaft forgings (Fig. 4) shall be performed using a current of 100 to 125 A/in. [4 to 5 A per mm] of bore diameter.

10.5.5 A suitable instrument such as ammeter shall be used to measure the specified or agreed upon current.

10.5.6 A magnetic particle field indicator (Fig. 8) where necessary shall be used to establish adequacy of the magnetic field. The magnetizing current shall be sufficient to develop the pattern in the indicator clearly.

10.5.6.1 The magnetic particle field indicator shall be used by positioning the indicator on the forging being examined while applying the required current and ferromagnetic particles. The production of a pattern (usually a cross) of discernible ferromagnetic particles indicates that adequate field strength has been generated in the forging being examined.

10.5.7 *Yoke Magnetization*—When electromagnetic yokes are used to magnetize a local area, a longitudinal field is formed between the poles.

10.5.7.1 *Equipment*—Yokes may be of the fixed or articulated leg types.

10.5.7.2 *Yoke Qualification*—Direct current electromagnetic yokes shall have a lifting power of at least 40 lbf [175 N] at a pole spacing of 3 to 6 in. [75 to 150 mm].

10.5.7.3 *Direction of Magnetization*—At least two separate examinations shall be carried out on each area. In the second examination, the lines of magnetic

flux shall be approximately perpendicular to those used for the first examination in that area.

10.5.7.4 *Pole Spacing*—Pole spacing shall be limited to 2 to 8 in. [50 to 200 mm].

10.5.7.5 *Inspection Area*—Inspection area is limited to a maximum distance of ¼ of the pole spacing on either side of a line joining the two poles. Overlapping of pole spacing shall be at least 1 in. [25 mm].

11. Application of Particles

11.1 While the forging is properly magnetized, the particles may be applied by one of the following methods:

11.1.1 *Dry Method*—In the dry method the particles shall be applied from a hand shaker (such as a shaker can), mechanical shaker, bulb blower, or mechanical blower. The use of the shaker shall be limited to flat and nearly horizontal surfaces, whereas the blowers may be used on vertical or overhead surfaces. The powder shall be applied evenly on the surface of the forging. The color of the dry powder should be chosen to provide suitable contrast. Too much powder is disadvantageous as it masks the patterns.

11.1.2 Care shall be exercised in blowing off excess power so as not to disturb the indications.

11.2 *Wet Methods:*

11.2.1 *Oil*—The material for the wet method is usually supplied in concentrate form, and the inspection medium shall be prepared by mixing the concentrate with a suitable light oil. The liquid recommended for the inspection vehicle is a well refined, light, petroleum distillate having a relatively high flash point. The approximate characteristics of a suitable liquid are as follows:

API gravity	46
Viscosity, SUS	31
Flash point (Tag Open Cup), °F [°C]	155 to 175 [65 to 80]
Initial boiling point, °F [°C]	390 [200]
End point, °F [°C]	490 [255]
Color, Saybolt	25

A suspension of from 1 to 2% solid material by volume shall generally be used. The inspection medium shall be flowed or sprayed over the area being inspected. The color of particles should be chosen to provide suitable contrast.

11.2.2 *Water*—Magnetic particles suspended in clean water, or clean water with suitable wetting agents may be used. Suspension of from 2 to 2½% solid material by volume shall generally be used.

11.3 *Fluorescent Method*—Fluorescent magnetic particle inspection is a variation of the wet method. A concentrate, similar to that used in the wet method, shall be used, except that the magnetic particle shall be coated with material that fluoresces when activated by "black" light.

11.3.1 The same procedure specified when mixing the wet medium shall be followed, except that the suspension shall contain 0.1 to 0.7% of solid material by volume when petroleum distillate or water is used.

11.3.2 The vehicle shall not be fluorescent.

11.3.3 If fluorescent particles are used, the examination shall be conducted in a darkened area using "black light," and the light intensity shall be at least 1000 $\mu W/cm^2$ at a distance of 15 in. from the lamp. The "black light" shall emit ultraviolet radiation of a wavelength within the range from 3300 to 3900 Å. The particles shall emit a brilliant fluorescence when subjected to this light. The bulb shall be allowed to warm up for a minimum of 5 min prior to its use in examination.

12. Demagnetization

12.1 When specified, parts shall be sufficiently demagnetized after inspection so that the residual field will not interfere with future welding or machining operations, magnetic instruments used in the proximity of the part, or so that leakage fields will not occur in areas of dynamic contact surfaces.

12.2 When direct current is used, demagnetizing may usually be accomplished by repeatedly reversing and progressively decreasing the magnetizing current. The initial field strength used during demagnetization shall be equal to or greater than the original magnetizing force. When the current has been reduced to the vanishing point, the part should be practically demagnetized. Direct current is recommended for demagnetizing large parts.

12.3 When alternating current is used, it is necessary merely to decrease the magnetizing current in smaller steps or continuously to a very low current.

12.4 Demagnetization will not be necessary if the piece is to be subject to an austenitizing treatment prior to future use or machining.

13. Interpretation and Evaluation of Indications

13.1 The following shall not be used as a standard for rejection or acceptance of a part, but may be used as an aid in interpreting and evaluating indications obtained. Examples of discontinuities and reference photographs of magnetic particle indications may be found in Practice E 709.

13.2 Factors that must be considered in interpreting an indication as to its cause are as follows:

13.2.1 Appearance of the indication.

13.2.2 Direction and shape of the indication.

13.2.3 Type of material from which the part is made.

13.2.4 Processing history of the part; type of machining; heat treatment; etc.

13.2.5 Past experience with similar parts based on destructive tests such as sectioning, etching, fracturing, chipping, grinding, etc.

13.3 The indications may be grouped into three broad classes:

13.3.1 Surface defects that produce sharp, distinct, clear-cut, tightly adhering patterns. These may generally be interpreted from characteristic indications as follows:

13.3.1.1 *Laminar Defects* give strong indications which are parallel to the surface.

13.3.1.2 *Forging Laps and Folds* are indications that may not be very heavy, and are not straight. They follow metal flow lines.

13.3.1.3 *Flakes* (thermal ruptures caused by entrapped hydrogen) can occur in areas that have been machined away. They are characterized by irregular, scattered indications.

13.3.1.4 *Heat-Treating Crack* indications are strong and occur at corners, notches, and changes of section.

13.3.1.5 *Shrinkage Crack* indications are very strong and sharp, usually continuous with few branches, and occur at changes of section.

13.3.1.6 *Grinding Crack* indications usually occur in groups at right angles to the direction of grinding.

13.3.1.7 *Etching or Plating Cracks* produce strong indications in a direction perpendicular to residual stresses.

13.3.2 Subsurface defects produce less distinct or fuzzy patterns which are broad rather than sharp, and are less tightly, held. They generally produce the following characteristic indications:

13.3.2.1 *Stringers of Nonmetallic Inclusions* often have strong indications like surface seams but are usually discontinuous or short and occur in groups. These indications follow the grain flow in forgings. The indications show only when the defects are near the surface.

13.3.2.2 *Large Nonmetallics* produce indications ranging from sharp to diffuse, which may occur anywhere in a section.

13.3.2.3 *Cracks in Underbeads of Welds* produce indications that occur in broad diffuse patterns.

13.3.2.4 *Forging Bursts* produce irregular and diffuse indications.

13.3.3 Nonrelevant or “false” indications are generally confusing but can usually be identified, as follows:

13.3.3.1 *Magnetic Writing* indications are fuzzy and will be destroyed by demagnetization. These indications are caused by contact with other steel or magnets while magnetized.

13.3.3.2 *Charges in Section* are indications that are broad and fuzzy and caused by concentration of magnetic field in gear teeth, fillets, keyways, etc.

13.3.3.3 *Edge of Weld* indications are caused by change of magnetic properties due to diffusion. These indications are not tightly adherent.

13.3.3.4 *Flow Lines* are large groups of parallel indications that occur particularly in forgings examined by means of excessive currents.

13.3.4 Any indication that is believed to be nonrelevant shall be regarded as unacceptable until the indication is either eliminated by surface conditioning or it is reexamined by the same or other nondestructive means and demonstrated to be nonrelevant.

14. Report of Indications

14.1 Record the size, number, and location of all linear indications. Use sketches to show location, direction, and frequency of indications. The report shall indicate the type of magnetization and location of contacts.

14.1.1 *Permanent Recording of Data:*

14.1.1.1 A permanent record of the indications may be made by carefully covering the surface with transparent, adhesive-backed, cellophane tape. The tape is then removed with particle indication adhering to it. The tape may then be placed on white paper or cardboard and photographed or otherwise reproduced.

14.1.1.2 If a more accurate reproduction of the indication is desired the following technique may be used. Once an indication has been detected using the normal examining technique, remove the accumulated powder and place a piece of white paper tape with a gloss surface and a gum adhesive backing over the area containing the indication; reapply the current and dust the tape with the powder. Immediately the particles will collect over the discontinuity, and with the current still passing through the test piece, spray the tape surface with a thin coating of acrylic lacquer. Terminate the current flow and remove the tape; this will leave an exact replica of the powder buildup adhering to it.

15. Acceptance Standards

15.1 The standards for acceptance of defects detected by magnetic particle examination shall be as specified in the applicable ASME product specification, contract, or order.

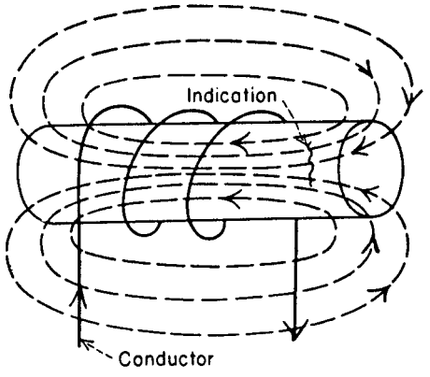


FIG. 1 LONGITUDINAL MAGNETIZATION

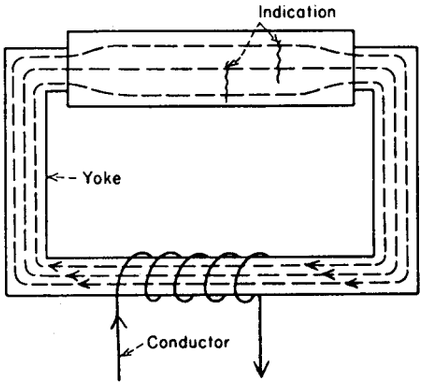


FIG. 2 LONGITUDINAL MAGNETIZATION, WITH YOKE

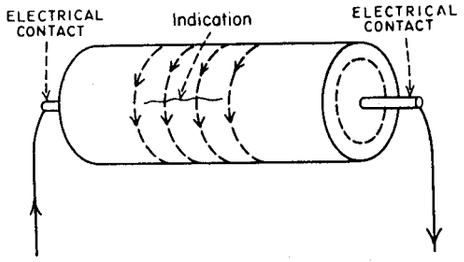


FIG. 3 CIRCULAR MAGNETIZATION, CURRENT DIRECTLY THROUGH FORGING

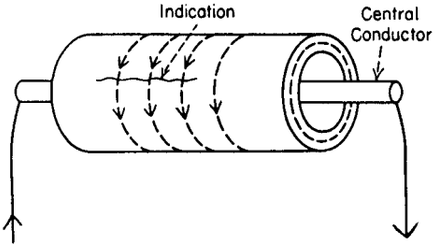


FIG. 4 CIRCULAR MAGNETIZATION, CURRENT THROUGH A CONDUCTOR

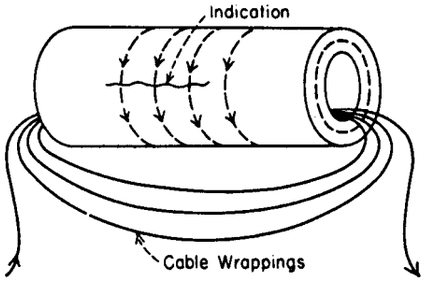


FIG. 5 CIRCULAR MAGNETIZATION, CURRENT THROUGH CONDUCTORS THREADED THROUGH FORGING

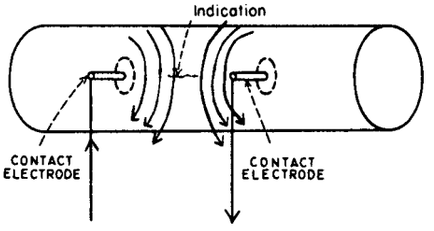


FIG. 6 CIRCULAR MAGNETIZATION WITH "PROD" TYPE CONTACT ELECTRODES

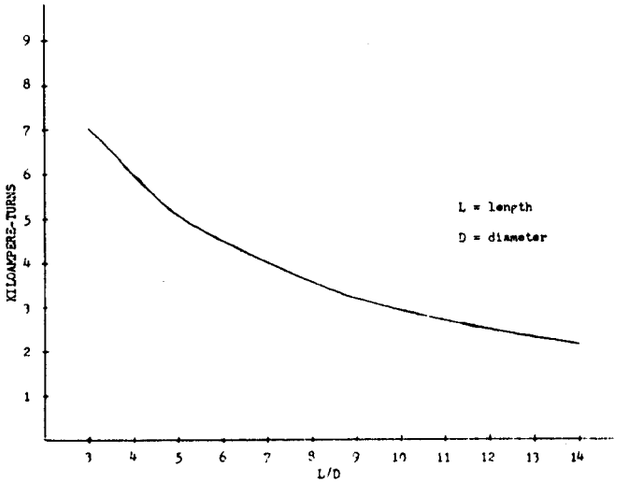


FIG. 7 LONGITUDINAL MAGNETIZATION

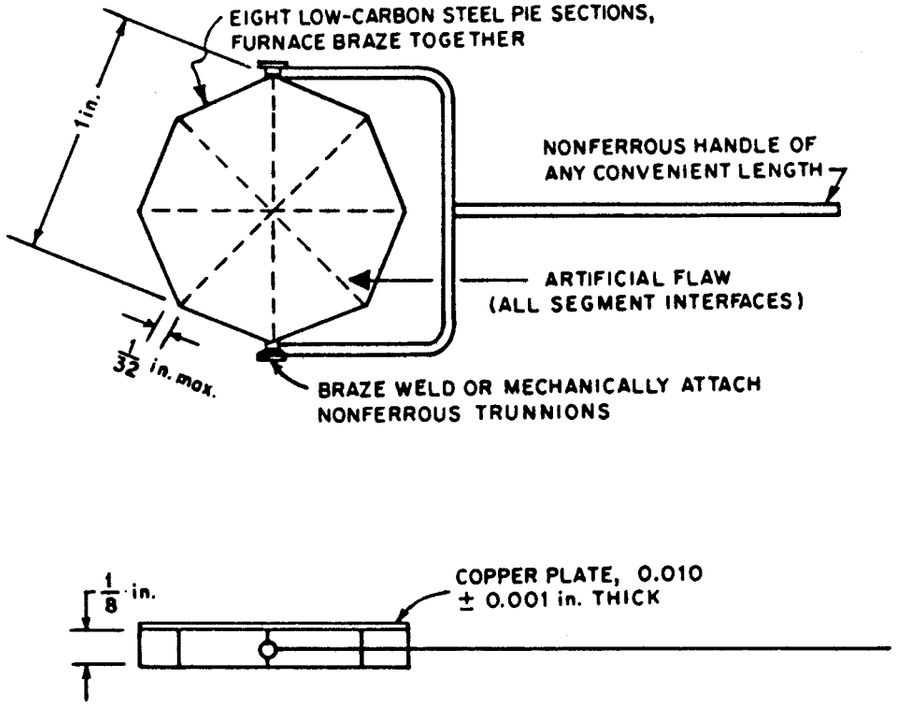


FIG. 8 MAGNETIC PARTICLE FIELD INDICATOR

SPECIFICATION FOR GRAY IRON CASTINGS FOR PRESSURE-CONTAINING PARTS FOR TEMPERATURES UP TO 650°F

SA-278

(Identical with ASTM Specification A 278-93.)

1. Scope

1.1 This specification covers gray iron for castings suitable for pressure-containing parts for use at temperatures up to 650°F.

1.2 Castings of all classes are suitable for use up to 450°F. For temperatures above 450°F and up to 650°F, only Class 40, 45, 50, 55, and 60 castings are suitable.

1.3 A complete SI companion to Specification A 278 has been developed — A 278M; therefore, no SI equivalents are presented in this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 278M Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 350°C [Metric]

A 644 Terminology Relating to Iron Castings

E 8 Test Methods for Tension Testing of Metallic Materials

3. Terminology

3.1 Definitions of many terms common to gray iron castings may be found in Terminology A 644.

4. Classification

4.1 Castings ordered to this specification are classified based upon the minimum tensile strength of the iron in ksi. Class 25 has a minimum specified tensile strength of 25 ksi.

5. Ordering Information

5.1 Orders for material in this specification should include the following information:

5.1.1 ASTM designation and year date,

5.1.2 Class of iron required and service temperature,

5.1.3 Quantity,

5.1.4 Whether or not heat treatment is required for Class 40, 45, 50, 55, and 60 castings to be used at temperatures at 450°F or less (see 6.2),

5.1.5 The size of separately cast test bar to be poured (see Section 9 and Table 1),

5.1.6 The size of test specimen to be machined from test bars C or S, and

5.1.7 Special requirements.

6. Materials and Manufacture

6.1 Castings intended for use above 450°F shall be stress-relieved by placing them in a suitable furnace at a temperature not exceeding 400°F and heating them

uniformly to the temperatures and for the times specified in Table 2. The heating and cooling rates shall be uniform and shall not be more than 400°F/h for castings of 1 in. maximum section. For heavier sections the maximum heating and cooling rates in degrees Fahrenheit per hour shall be 400 divided by the maximum section thickness.

6.2 Castings of Class Nos. 40, 45, 50, 55, and 60, which are to be used at temperatures below 450°F, may be heat treated in accordance with 6.1 or they shall be cooled in the mold to 500°F at an average rate of not more than 100°F/h for castings up to 1 in. in section. For heavier sections the maximum cooling rate in degrees Fahrenheit per hour shall be 100 divided by the maximum section thickness.

7. Chemical Composition

7.1 Class 40, 45, 50, 55, and 60 castings intended for service above 450°F shall have a maximum carbon equivalent of 3.8% as calculated from the equation CE = %C + 0.3 (%Si + %P). The maximum phosphorus and sulfur contents shall be 0.25% and 0.12%, respectively.

7.2 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or thin wafers approximately $\frac{1}{32}$ in. thick cut from test coupons. Drillings shall not be used because of attendant loss of graphite.

8. Tensile Requirements

8.1 Iron used in supplying castings to this specification shall conform to the tensile requirements prescribed in Table 3.

9. Test Bars

9.1 Separately cast test bars having the dimensions shown in Table 1 shall be poured from the same lot as the castings represented. The size of the test bar to be poured shall be selected by the purchaser using Table 4. In the event no choice is made, the selection will be made by the manufacturer.

9.2 Separately cast test bars shall be heat treated in the same furnace together with the castings represented.

9.3 At the option of the manufacturer, test coupons may be removed from the casting at a location agreed upon between the manufacturer and purchaser.

9.4 Castings weighing in excess of 2000 lb may be represented either by separately cast test bars (9.1) or by integrally cast test bars having a cooling rate closely approximating that of the controlling section of the casting.

9.5 For castings weighing in excess of 10 000 lb or having a controlling section greater than 2 in., test bars may be removed from the casting or integral projections having a cross section no less than the controlling section. The minimum tensile strength requirement for tension tests performed on either of these test bars shall be 80% of the specified class.

10. Molding and Pouring Test Bars

10.1 The test bars shall be cast in dried siliceous sand molds maintained at approximately room temperature. A suitable design for a mold is shown in Fig. 1.

11. Tension Test Specimens

11.1 Tension test specimens A and B in Fig. 2 shall be machined from test bars A and B in Table 1, respectively.

11.2 The purchaser shall specify whether test specimen B or C is to be machined from test bar C. If no choice is made, the manufacturer shall make the selection.

11.3 The size of the test specimen to be machined from test bar S shall be as agreed upon between the manufacturer and purchaser.

12. Number of Tests and Retests

12.1 One tension test shall be performed on each lot in accordance with Test Method E 8 and conform to the tensile requirements specified.

12.2 If the results of a valid test fail to conform to the requirements of this specification, two retests shall be made. If either retest fails to meet the specification requirements, the castings represented by these test specimens shall be rejected.

12.3 If, after testing, a test specimen shows evidence of a defect, the results of the test may be invalidated and another made on a specimen from the same lot.

13. Sampling

13.1 A lot shall consist of one of the following:

13.1.1 All the metal poured from a single heating in a batch type melting furnace,

13.1.2 All the metal from two or more batch type melting furnaces poured into a single ladle or single casting, or

13.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry or 4 h, whichever is the shorter period.

13.1.3.1 The purchaser may agree to extend the 4-h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

14. Workmanship, Finish, and Appearance

14.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser. If the pattern is supplied by the purchaser without drawings, the dimensions of the casting shall be as predicted by the pattern.

14.2 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order.

15. Repair

15.1 Any repairs performed on castings produced to this specification shall be agreed upon between the manufacturer and purchaser.

16. Certification

16.1 When requested by the purchaser, the manufacturer shall furnish his certification stating that the material was manufactured, sampled, tested, and inspected in accordance with this specification including the year date. The certification shall also include the results of all tests performed.

16.2 A signature is not required on the certification. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

17. Inspection

17.1 All tests and inspections required by this specification shall be performed by the manufacturer or other reliable sources whose services have been contracted for by the manufacturer. Complete records of all tests and inspections shall be maintained by the manufacturer and shall be available for review by the purchaser.

18. Rejection and Rehearing

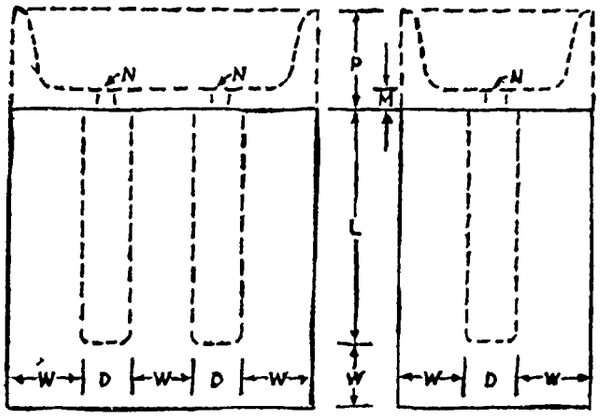
18.1 Castings which fail to conform to the requirements specified when inspected or tested by the purchaser or his agent may be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the test results, the manufacturer or supplier may make claim for a rehearing.

19. Product Marking

19.1 Castings shall have the name of the manufacturer, or his recognized trademark, and the class of iron to which it conforms, cast or indelibly stamped on a surface indicated by the purchaser or in such a position as not to injure the usefulness of the casting.

20. Keywords

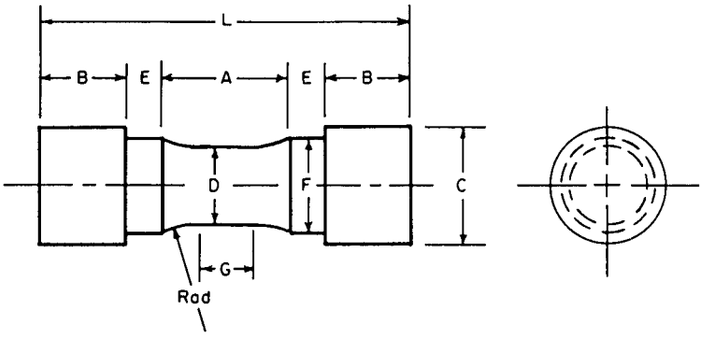
20.1 elevated temperature service; gray iron castings; pressure containing parts



Number of test bars in a single mold-2 suggested.
L—see Table 1.
D—see Table 1.
W—not less than diameter, *D*.

P—2 in. suggested
N—5/16 in. in diameter, suggested
M—1.5 *N*, suggested

FIG. 1 SUITABLE DESIGN AND DIMENSIONS FOR MOLD FOR SEPARATELY CAST CYLINDRICAL TEST BARS FOR GRAY IRON



Dimensions, in.	Tension Test Specimen A	Tension Test Specimen B	Tension Test Specimen C
G—Length of parallel, min	0.50	0.75	1.25
D—Diameter	0.500 ± 0.010	0.750 ± 0.015	1.25 ± 0.025
R— Radius of fillet, min	1	1	2
A—Length of reduced section, min	1 1/4	1 1/2	2 1/4
L—Overall length, min	3 3/4	4	6 3/8
C—Diameter of end section, approximate	7/8	1 1/4	1 7/8
E—Length of shoulder, min	1/4	1/4	5/16
F—Diameter of shoulder	5/8 ± 1/64	15/16 ± 1/64	1 7/16 ± 1/64
B—Length of end section	[A]	[A]	[A]

[A] Optional to fit holders on testing machine. If threaded, root diameter shall not be less than dimension *F*.

FIG. 2 TENSION-TEST SPECIMENS

TABLE 1
DIAMETERS AND LENGTHS OF CAST TEST BARS

Test Bar	As-Cast Diameter, in.			Length, in.	
	Nominal (Mid-Length)	Minimum (Bottom)	Maximum (Top)	Minimum (Specified)	Maximum (Recommended)
A	0.88	0.85	0.96	5.0	6.0
B	1.20	1.14	1.32	7.0	9.0
C	2.00	1.90	2.10	6.0	10.0
S[A]					

[A] All dimensions of Test Bar S shall be as agreed upon by the manufacturer and the purchaser.

TABLE 2
STRESS RELIEVING REQUIREMENTS

Class	Metal Temperature, °F	Holding Time, h[A]	
		Minimum	Maximum
40, 45, 50, 55, 60	1050 to 1200	2	12

[A] In no case shall the holding time be less than 1 h/in. of maximum metal section, or in excess of 12 h maximum, dependent upon which governs.

TABLE 3
TENSILE REQUIREMENTS

Class	Tensile Strength, min, ksi
No. 20	20
No. 25	25
No. 30	30
No. 35	35
No. 40	40
No. 45	45
No. 50	50
No. 55	55
No. 60	60

TABLE 4
SEPARATELY CAST TEST BARS FOR USE WHEN A SPECIFIC CORRELATION HAS NOT BEEN ESTABLISHED BETWEEN THE TEST BAR AND THE CASTING

Thickness of the Wall of the Controlling Section of the Casting, in.	Test Bar
Under 0.25	S
0.25 to 0.50	A
0.51 to 1.00	B
1.01 to 2	C
Over 2	S

SPECIFICATION FOR LOW AND INTERMEDIATE TENSILE STRENGTH CARBON STEEL PLATES

SA-283/SA-283M

(Identical with ASTM Specification A 283/A 283M-93.)

1. Scope

1.1 This specification covers four grades (A, B, C, and D) of carbon steel plates of structural quality for general application.

1.2 When the steel is to be welded, it is presupposed that a welding procedure suitable for the grade of steel and intended use or service will be utilized.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not equivalents, therefore each system must be used independent of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Document

2.1 *ASTM Standard:*

A 6/A 6M Specification for General Requirements for Rolled Steel Plates, Shapes, Sheet Piling, and Bars for Structural Use

3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 6/A 6M, for the ordered material, unless a conflict exists in which case this specification shall prevail.

4. Process

4.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

5. Chemical Requirements

5.1 The heat analysis shall conform to the requirements prescribed in Table 1.

5.2 The steel shall conform on product analysis to the requirements prescribed in Table 1, subject to the product analysis tolerances in Specification A 6/A 6M.

6. Tensile Requirements

6.1 Material as represented by the test specimens shall conform to the requirements as to tensile properties prescribed in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Heat Analysis, %			
	Grade A	Grade B	Grade C	Grade D
Carbon, max	0.14	0.17	0.24	0.27
Manganese, max	0.90	0.90	0.90	0.90
Phosphorus, max	0.035	0.035	0.035	0.035
Sulfur, max	0.04	0.04	0.04	0.04
Silicon				
Plates 1½ in. [40 mm] and under, max	0.40	0.40	0.40	0.40
Plates over 1½ in. [40 mm]	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Copper, min % when copper is specified	0.20	0.20	0.20	0.20

TABLE 2
TENSILE REQUIREMENTS[A]

	Grade A	Grade B	Grade C	Grade D
Tensile strength, ksi [MPa]	45–60 [310–415]	50–65 [345–450]	55–75 [380–515]	60–80 [415–550]
Yield point, min, ksi [MPa]	24 [165]	27 [185]	30 [205]	33 [230]
Elongation in 8 in. [200 mm], min, %[B]	27	25	22	20
Elongation in 2 in. [50 mm], min, %[B]	30	28	25	23

[A] See Specimen Orientation under the Tension Tests section of Specification A6/A 6M.
[B] For plates wider than 24 in. [600 mm], the elongation requirement is reduced two percentage points. See elongation requirement adjustments in the Tension Tests section of Specification A 6/A 6M.

SUPPLEMENTARY REQUIREMENTS

Standardized supplementary requirements for use at the option of the purchaser are listed in Specification A 6/A 6M. Several that are considered suitable for use with this specification are listed by title:

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S8. Ultrasonic Examination,

S14. Bend Test, and

S15. Reduction of Area.

S97. Limitation on Rimmed or Capped Steel:

S97.1 The steel shall be other than rimmed or capped.

Supplementary requirements shall not apply unless specified on the order. Requirements other than those shown above may be specified subject to agreement between the supplier and the purchaser.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, LOW- AND INTERMEDIATE-TENSILE STRENGTH

SA-285/SA-285M

(Identical with ASTM Specification A 285/A 285M-90) 98

1. Scope

1.1 This specification covers carbon steel plates of low- and intermediate-tensile strengths which may be made by killed, semi-killed, capped, or rimmed steel practices at the producer's option. These plates are intended for fusion-welded pressure vessels.

1.2 Plates under this specification are available in three grades having different strength levels as follows:

Grade	Tensile Strength, ksi (MPa)
A	45–65 (310–450)
B	50–70 (345–485)
C	55–75 (380–515)

98 **1.3** The maximum thickness of plates under this specification, for reasons of internal soundness, is limited to a maximum thickness of 2 in. (50 mm) for all grades.

NOTE—For killed carbon steels only refer to the following ASTM specifications:

A 299, Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
A 515 Pressure Vessel Plates, Carbon Steel, for Intermediate and Higher Temperature Service
A 516 Pressure Vessel Plates, Carbon Steel, for Moderate and Lower Temperature Service

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Applicable Document

2.1 *ASTM Standard:*
A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control testing or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.4 If the requirements of this specification are in conflict with the requirements of Specification A 20/

A 20M, the requirements of this specification shall prevail.

4. Heat Treatment

4.1 Plates are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5. Chemical Requirements

5.1 The steel shall conform to the requirements as to chemical composition shown in Table 1. 98

6. Mechanical Requirements

6.1 *Tension Tests:*

6.1.1 *Requirements:*

6.1.1.1 The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

98

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max[A]	0.17	0.22	0.28
Manganese, max			
Heat analysis	0.90	0.90	0.90
Product analysis	0.98	0.98	0.98
Phosphorus, max[A]	0.035	0.035	0.035
Sulfur, max[A]	0.035	0.035	0.035

[A] Applied to both heat and product analysis.

TABLE 2
TENSILE REQUIREMENTS

	Grade A		Grade B		Grade C	
	ksi	[MPa]	ksi	[MPa]	ksi	[MPa]
Tensile strength	45–65	[310–450]	50–70	[345–485]	55–75	[380–515]
Yield strength, min[A]	24	[165]	27	[185]	30	[205]
Elongation in 8 in. or [200 mm], min, %[B]	27		25		23	
Elongation in 2 in. or [50 mm], min, %	30		28		27	

[A] Determined by either the 0.2% offset method or the 0.5% extension-under-load method.
[B] See Specification A 20/A 20M.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

98 **S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons.**

S4.1 Additional Tension Test.

S14. Bend Test.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below are additional optional supplementary requirements suitable for this specification.

98 **S57. Copper-Bearing**

S57.1 The copper content, by heat analysis shall be 0.20–0.35% and by product analysis 0.18–0.37%.

98 **S58. Restricted Copper**

S58.1 The maximum incidental copper content by heat analysis shall not exceed 0.25%.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, MANGANESE-SILICON

SA-299/SA-299M

(Identical with ASTM Specification A 299/A 299M-90.) 98

1. Scope

1.1 This specification covers manganese-silicon carbon steel plates for use in welded boilers and other pressure vessels.

1.2 Plates under this specification are produced in one grade only; however, the yield strength decreases on thicknesses over 1 in. [25 mm]:

Thickness	Tensile Strength, ksi [MPa]	Yield Strength, ksi [MPa]
Up to 1 in. [25 mm]	75–95 [515–655]	42 [290]
Over 1 in. [25 mm]	75–95 [515–655	40 [275]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limit, the maximum thickness of plates furnished under this specification to 8 in. [200 mm].

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Applicable Document

2.1 *ASTM Standard:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the basis of purchase that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed.

5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. Plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 2 in. [50 mm] in thickness shall be normalized.

6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition as shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %
Carbon, max[A]:	
1 in. [25 mm] and under	0.28
Over 1 in. [25 mm]	0.30
Manganese:	
1 in. [25 mm] and under	
Heat analysis	0.90 to 1.40
Product analysis	0.84 to 1.52
Over 1 in. [25 mm]	
Heat analysis	0.90 to 1.50
Product analysis	0.84 to 1.62
Phosphorus, max[A]	0.035
Sulfur, max[A]	0.040
Silicon:	
Heat analysis	0.15 to 0.40
Product analysis	0.13 to 0.45

[A] Applies to both heat and product analysis.

TABLE 2
TENSILE REQUIREMENTS

Tensile strength, ksi [MPa]	75–95 [515–655]
Yield strength, min,[A] ksi [MPa]:	
1 in. [25 mm] and under	42 [290]
Over 1 in. [25 mm]	40 [275]
Elongation in 8 in. [200 mm], min, %	16[B]
Elongation in 2 in. [50 mm], min, %	19[B]

[A] Determined by either the 0.2% offset method or the 0.5% extension-under-load method.
[B] See Specification A 20/A 20M.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, MANGANESE-MOLYBDENUM AND MANGANESE-MOLYBDENUM-NICKEL

SA-302/SA-302M

(Identical with ASTM Specification A 302/A 302M-93.)

1. Scope

1.1 This specification covers manganese-molybdenum and manganese-molybdenum-nickel alloy steel plates intended particularly for welded boilers and other pressure vessels.

1.2 Material under this specification is available in four grades having different strength levels as follows:

Grade	Tensile Strength, ksi [MPa]	Type
A	75–95 [515–655]	Mn-Mo
B	80–100 [550–690]	Mn-Mo
C	80–100 [550–690]	Mn-Mo-Ni
D	80–100 [550–690]	Mn-Mo-Ni

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements. The minimum thickness is limited to 0.25 in. [6.5 mm].

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Document

2.1 *ASTM Standard:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed.

5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. Plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 2 in. [50 mm] in thickness shall be normalized.

5.3 When normalizing plates 4 in. [100 mm] or over in thickness, the cooling rate may be accelerated by air blasting or liquid quenching to obtain mechanical properties comparable to those developed by normalizing plates in the lesser thicknesses.

5.4 If approved by the purchaser, for plates less than 4 in. [100 mm] in thickness, cooling rates faster than those obtained by cooling in air are permissible for improvement of toughness, provided the plates are subsequently tempered in the temperature range from 1100 to 1300°F [595 to 705°C].

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension-Test Requirements* — The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.1.1 For accelerated cooled plates with a nominal thickness of $\frac{3}{4}$ in. [20 mm] or less, the $1\frac{1}{2}$ in. [40 mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %			
	Grade A	Grade B	Grade C	Grade D
Carbon, max[A]:				
Up to 1 in. [25 mm], incl, in thickness	0.20	0.20	0.20	0.20
Over 1 to 2 in. [50 mm], incl	0.23	0.23	0.23	0.23
Over 2 in. [50 mm] in thickness	0.25	0.25	0.25	0.25
Manganese:				
Heat analysis	0.95–1.30	1.15–1.50	1.15–1.50	1.15–1.50
Product analysis	0.87–1.41	1.07–1.62	1.07–1.62	1.07–1.62
Phosphorus, max[A]	0.035	0.035	0.035	0.035
Sulfur, max[A]	0.035	0.035	0.035	0.035
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45
Molybdenum:				
Heat analysis	0.45–0.60	0.45–0.60	0.45–0.60	0.45–0.60
Product analysis	0.41–0.64	0.41–0.64	0.41–0.64	0.41–0.64
Nickel:				
Heat analysis	. . .	. . .	0.40–0.70	0.70–1.00
Product analysis	. . .	. . .	0.37–0.73	0.67–1.03

[A] Applies to both heat and product analysis.

TABLE 2
TENSILE REQUIREMENTS

	Grade A	Grade B	Grade C	Grade D
Tensile strength, ksi [MPa]	75–95 [515–655]	80–100 [550–690]	80–100 [550–690]	80–100 [550–690]
Yield strength, min, ksi [MPa]	45 [310]	50 [345]	50 [345]	50 [345]
Elongation in 8 in. [200 mm], min, %	15[A]	15[A]	17[A]	17[A]
Elongation in 2 in. [50 mm], min, %	19[A]	18[A]	20[A]	20[A]

[A] See Specification A 20/A 20M.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR CARBON STEEL BOLTS AND STUDS, 60,000 PSI TENSILE STRENGTH

SA-307

(Identical with ASTM Specification A 307-93a.)

1. Scope

1.1 This specification covers the chemical and mechanical requirements of three grades of carbon steel bolts and studs in sizes ¼ in. (6.35 mm) through 4 in. (104 mm). The fasteners are designated by "Grade" denoting tensile strength and intended use, as follows:

Grade	Description
Grade A	Bolts and studs having a minimum tensile strength of 60 ksi (414 MPa) and intended for general applications,
Grade B	Bolts and studs having a tensile strength of 60 to 100 ksi (414 to 690 MPa) and intended for flanged joints in piping systems with cast iron flanges, and
Grade C	Nonheaded anchor bolts (studs), either bent or straight, having properties conforming to Specification A 36 (tensile strength of 58 to 80 ksi (400 to 550 MPa)) and intended for structural anchorage purposes.

1.1.1 The term *studs* includes stud stock, sometimes referred to as *threaded rod.*

1.2 This specification does not cover requirements for machine screws, thread cutting/forming screws, mechanical expansion anchors or similar externally threaded fasteners.

1.3 Suitable nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut for each grade of fastener, of all surface finishes, shall be as follows:

Fastener Grade and Size	Nut Grade and Style[A]
A, C, ¼ to 1½ in.	A, hex
A, C, over 1½ to 4 in.	A, heavy hex
B, ¼ to 4 in.	A, heavy hex

[A] Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nut are also suitable.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 Supplementary Requirement S1 of an optional nature is provided, which describes additional restrictions to be applied when bolts are to be welded. It shall apply only when specified in the inquiry, order, and contract.

2. Referenced Documents

2.1 *ASTM Standards:*

A 36 Specification for Structural Steel
A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 370 Test Methods ad Definitions for Mechanical Testing of Steel Products
A 563 Specification for Carbon and Alloy Steel Nuts
A 706/A 706M Specification for Low-Alloy Steel Deformed Bars for Concrete Reinforcement
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
D 3951 Practice for Commercial Packaging
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

2.2 *ANSI/ASME Standards:*

B1.1 Unified Screw Threads
B18.2.1 Square and Hex Bolts and Screws

2.3 *Military Standard:*
MIL-STD 105 Single Sampling Plan for Normal Inspection

3. Ordering Information

3.1 Orders for externally threaded fasteners (including nuts and accessories) under this specification shall include the following:

3.1.1 ASTM designation and year of issue,

3.1.2 Name of product, bolts or studs; and bolt head style, that is, hex or heavy hex,

3.1.3 Grade, that is, A, or B, or C. If no grade is specified, Grade A is furnished.

3.1.4 Quantities (number of pieces by size including nuts),

3.1.5 Fastener size and length,

3.1.6 *Washers* — Quantity and size (separate from bolts),

3.1.7 *Zinc Coating* — Specify the zinc-coating process required for example, hot-dip, mechanically deposited or no preference (see 4.5),

3.1.8 *Other Finishes* — Specify other protective finish, if required,

3.1.9 Specify if inspection at point of manufacture is required,

3.1.10 Specify if certified test report is required (see 8.2), and

3.1.11 Specify additional testing (8.3) or special requirements.

4. Materials and Manufacture

4.1 Steel for bolts and studs shall be made by the open-hearth, basic-oxygen, or electric-furnace process.

4.2 Bolts may be produced by hot or cold forging of the heads or machining from bar stock.

4.3 *Heat Treatment:*

4.3.1 Cold headed fasteners with head configurations other than hex shall be stress relief annealed.

4.3.2 Hex head fasteners may be stress relieved at the manufacturer's option.

4.4 Bolt and stud threads may be rolled or cut.

4.5 *Zinc Coatings, Hot-Dip and Mechanically Deposited:*

4.5.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc-coating process, for example hot dip, mechanically deposited, or no preference.

4.5.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153.

4.5.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical-deposition process in accordance with the requirements of Class 50 of Specification B 695.

4.5.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier's option is limited to one process per item with no mixed processes in a lot.

5. Chemical Composition

5.1 Grade A and B bolts and studs shall conform to the following chemical requirements:

	Grade A	Grade B
Phosphorus, max, %	0.06	0.04
Sulfur, max, %	0.15	0.05

5.2 Grade C nonheaded anchor bolts shall conform to the chemical requirements in Specification A 36 for bars.

5.3 Resulfurized material is not subject to rejection based on product analysis for sulfur.

5.4 Bolts and studs are customarily furnished from stock, in which case individual heats of steel cannot be identified.

5.5 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for Grade B bolts and studs.

5.6 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 Grades A and B bolts and studs shall conform to the hardness specified in Table 1.

6.2 Grade A and B bolts and studs 1½ in. in diameter or less, other than those excepted in 6.4, shall be tested full size and shall conform to the requirements for tensile strength specified in Table 2.

6.3 Grade A and B bolts and studs larger than 1½ in. in diameter, other than those excepted in 6.4, shall preferably be tested full size and when so tested, shall conform to the requirements for tensile strength specified in Table 2. When equipment of sufficient capacity for full-size bolt testing is not available, or when the length of the bolt makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements specified in Table 3.

6.4 Grades A and B bolts and studs less than three diameters in length or bolts with drilled or undersize heads are not subject to tensile tests.

6.5 Grade C nonheaded anchor bolts shall be tested using machined specimens and shall conform to the tensile properties specified for bars in Specification A 36. Properties are shown in Table 3 for information. In the event of conflict Specification A 36 shall control.

6.6 In the event that bolts are tested by both full size and by machine test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

6.7 For bolts and studs on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low readings of hardness tests.

7. Dimensions

7.1 Unless otherwise specified, threads shall be the Coarse Thread Series as specified in the latest issue of ANSI/ASME B1.1, and shall have a Class 2A tolerance.

7.2 Unless otherwise specified, Grade A bolts shall be hex bolts with dimensions as given in the latest issue of ANSI/ASME B18.2.1. Unless otherwise specified, Grade B bolts shall be heavy hex bolts with dimensions as given in the latest issue of ANSI/ASME B18.2.1.

7.3 Unless otherwise specified, bolts and studs to be used with nuts or tapped holes which have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot-dip or mechanically deposited zinc coating. After zinc coating the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

Diameter, in.	Oversize Limit, in. (mm)[A]
¼	0.016
5/16, ⅜	0.017
7/16, ½	0.018
9/16 to ¾ incl	0.020
⅞	0.022
1.0 to 1¼ incl	0.024
1⅜, 1½	0.027
1¾ to 4.0 incl	0.050

[A] These values are the same as the overtapping required for zinc-coated nuts in Specification A 563.

7.4 The gaging limit for bolts and studs shall be verified during manufacture or use by assembly of a nut tapped as nearly as practical to the amount oversize shown above. In case of dispute, a calibrated thread ring gage of that same size (Class X tolerance, gage tolerance plus) shall be used. Assembly of the gage, or the nut described above, must be possible with hand effort following application of light machine oil to prevent galling and damage to the gage. These inspections, when performed to resolve disputes, shall be performed at the frequency and quality described in Table 4.

8. Number of Tests and Retests

8.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

8.2 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

8.3 When additional tests are specified on the purchase order, a lot, for purposes of selecting test samples, shall consist of all material offered for inspection at one time that has the following common characteristics:

8.3.1 One type of item,

8.3.2 One nominal size, and

8.3.3 One nominal length of bolts and studs.

8.4 From each lot, the number of tests for each requirement shall be as follows:

Number of Pieces in Lot	Number of Samples
800 and under	1
801 to 8000	2
8001 to 22 000	3
Over 22 000	5

8.5 If any machined test specimen shows defective machining, it may be discarded and another specimen substituted.

8.6 Should any sample fail to meet the requirements of a specified test, double the number of samples from the same lot shall be tested, in which case all of the additional samples shall meet the specification.

9. Test Methods

9.1 Grades A and B bolts and studs shall be tested in accordance with Test Methods F 606.

9.2 Grade C nonheaded anchor bolts shall have machined specimen tension tests made on the bolt body or on the bar stock used for making the anchor bolts. Tests on finished anchor bolts shall be made in accordance with Test Methods F 606 and tests on bar stock in accordance with Specification A 36 and Test Methods A 370.

9.3 Standard square and hex head bolts only shall be tested by the wedge tension method except as noted in 6.4. Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body. Other headed bolts shall be tested by the axial tension method.

9.4 Speed of testing as determined with a free running crosshead shall be a maximum of 1 in. (25.4 mm)/min for the tensile strength tests of bolts.

10. Inspection

10.1 If the inspection described in 10.2 is required by the purchaser it shall be specified in the inquiry, order, or contract.

10.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

11. Responsibility

11.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with this specification and meets all of its requirements.

12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13. Product Marking

13.1 Bolt heads and one end of studs shall be marked with a unique identifier by the manufacturer to identify the manufacturer or private label distributor, as appropriate. The manufacturer may also use additional marking for his own use.

13.2 In addition to the requirements of 13.1, all bolt heads, one end of studs $\frac{3}{8}$ in. and larger, and whenever feasible studs less than $\frac{3}{8}$ in. shall be marked with a grade marking as follows:

Grade	Marking
A	307A
B	307B
C	307C

13.3 All markings shall be located on the top of the bolt head or stud end and may be raised or depressed at the option of the manufacturer.

13.4 Grade and manufacturer's or private label distributor's identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

14. Packaging and Package Marking

14.1 *Packaging:*

14.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

14.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

14.2 *Package Marking:*

14.2.1 Each shipping unit shall include or be plainly marked with the following information:

14.2.1.1 ASTM designation and grade,

14.2.1.2 Size,

14.2.1.3 Name and brand or trademark of the manufacturer,

14.2.1.4 Number of pieces,

14.2.1.5 Purchase order number,

14.2.1.6 Country of origin.

15. Keywords

15.1 bolts; carbon steel; steel; studs

TABLE 1
HARDNESS REQUIREMENTS FOR BOLTS AND STUDS

		Hardness[A]			
		Brinell		Rockwell B	
Grade	Length, in. 0	min	max	min	max
A	Less than 3 × dia[B]	121	241	69	100
	3 × dia and longer	. . .	241	. . .	100
B	Less than 3 × dia[B]	121	212	69	95
	3 × dia and longer	. . .	212	. . .	95
C	All		No hardness required		

[A] As measured anywhere on the surface or through the cross section.
[B] Also bolts with drilled or undersize heads. These sizes and bolts with modified heads shall meet the minimum and maximum hardness as hardness is the only requirement.

TABLE 2
TENSILE REQUIREMENTS FOR FULL-SIZE BOLTS AND STUDS

Bolt Size, in.	Threads per Inch	Stress Area,[A] in.^{2}	Tensile Strength, lbf[B]		
			Grade A, min[C]	Grade B	
				min[D]	max[D]
1/4	20	0.0318	1 900	1 900	3 180
5/16	18	0.0524	3 100	3 100	5 240
3/8	16	0.0775	4 650	4 650	7 750
7/16	14	0.1063	6 350	6 350	10 630
1/2	13	0.1419	8 500	8 500	14 190
9/16	12	0.182	11 000	11 000	18 200
5/8	11	0.226	13 550	13 550	22 600
3/4	10	0.334	20 050	20 050	33 400
7/8	9	0.462	27 700	27 700	46 200
1	8	0.606	36 350	36 350	60 600
1 1/8	7	0.763	45 800	45 800	76 300
1 1/4	7	0.969	58 150	58 150	96 900
1 3/8	6	1.155	69 300	69 300	115 500
1 1/2	6	1.405	84 300	84 300	140 500
1 3/4	5	1.90	114 000	114 000	190 000
2	4 1/2	2.50	150 000	150 000	250 000
2 1/4	4 1/2	3.25	195 000	195 000	325 000
2 1/2	4	4.00	240 000	240 000	400 000
2 3/4	4	4.93	295 800	295 800	493 000
3	4	5.97	358 200	358 200	597 000
3 1/4	4	7.10	426 000	426 000	710 000
3 1/2	4	8.33	499 800	499 800	833 000
3 3/4	4	9.66	579 600	579 600	966 000
4	4	11.08	664 800	664 800	1 108 000

[A] Area calculated from the equation:

$$A_s = 0.7854\,[D - (0.9743/n)]^2$$

where:
A_s = stress area,
D = nominal diameter of bolt, and
n = threads per inch.

[B] 1 lbf = 4.448 N.
[C] Based on 60 ksi (414 MPa).
[D] Based on 60–100 ksi (414–690 MPa).

TABLE 3
TENSILE REQUIREMENTS FOR MACHINED SPECIMENS

	Grade A	Grade B	Grade C
Tensile strength, ksi (MPa)	60 (415) min	60–100 (415–690)	58–80 (400–550)
Yield point, min ksi (MPa)	. . .	. . .	36 (50)
Elongation in 2 in. (50 mm), min, %	18	18	23

TABLE 4
SAMPLE SIZES AND ACCEPTANCE NUMBERS FOR INSPECTION OF HOT-DIP OR MECHANICALLY DEPOSITED ZINC-COATED THREADS

Lot Size	Sample Size[A,B]	Acceptance Number[A]
2 to 90	13	1
91 to 150	20	2
151 to 280	32	3
281 to 500	50	5
501 to 1 200	80	7
1 201 to 3 200	125	10
3 201 to 10 000	200	14
10 001 and over	315	21

[A] Sample sizes of acceptance numbers are extracted from "Single Sampling Plan for Normal Inspection," Table IIA, MIL-STD-105.
[B] Inspect all bolts in the lot if the lot size is less than the sample size.

SUPPLEMENTARY REQUIREMENT

The following supplementary requirement shall apply only when specified in the purchase order or contract:

S1. Bolts Suitable for Welding

S1.1 The material described in this section is intended for welding. This supplemental section, by additional chemical composition restrictions and by a carbon equivalent formula, provides assurance of weldability by chemical composition control.

S1.2 Welding technique is of fundamental importance when bolts produced to this supplementary section are welded. It is presupposed that suitable welding procedures for the steel being welded and the intended service will be selected.

S1.3 All of the requirements of this supplemental section apply in addition to all of the chemical, mechanical, and other requirements of the base specification, Specification A 307 for Grade B.

S1.4 Because of the embrittling effects of welding temperatures on cold-forged steel, this supplemental section is limited to hot-forged bolts, or, if not forged, then to bolts produced from hot-rolled bars without forging or threaded bars, bars studs, or stud bolts produced from hot-rolled bars without forging. Cold-forged bolts, or cold-drawn threaded bars, if they are given a thermal treatment by heating to a temperature of not less than 1500°F (815°C) and air-cooled are also suitable.

S1.5 *Chemical Requirements:*

S1.5.1 *Heat Chemical Analysis* — Material conforming to the following additional analysis limitations shall be used to manufacture the product described in this supplementary requirement.

Carbon	0.30%, max
Manganese	1.00%, max
Phosphorus	0.04%, max
Sulfur	0.05%, max
Silicon	0.50%, max

S1.5.2 *Carbon Equivalent (Source — Specification A 706/A 706M)* — In addition to the heat chemical analysis requirements in S1.5.1, the heat analysis shall be such as to provide a carbon equivalent (CE) not exceeding 0.55 when calculated as follows:

$$CE = \%\,C + \frac{\%\,Mn}{6} + \frac{\%\,Cu}{40} + \frac{\%\,Nl}{20} + \frac{\%\,Cr}{10} - \frac{\%\,Mo}{50} - \frac{\%\,V}{10}$$

S1.6 *Analysis Reports* — If requested on the order or contract, the chemical composition of each heat of steel used and the calculated carbon equivalent for each heat shall be reported to the purchaser.

S1.7 *Product (Check) Verification Analysis* — A chemical analysis may be made by the purchaser or his representative from bolts selected from each heat of steel. The analysis thus determined shall not exceed the values specified in S1.5.2 by more than the following amounts.

	%
Carbon	+0.03
Manganese	+0.06
Phosphorus	+0.008
Sulfur	+0.008
Silicon	+0.05

SPECIFICATION FOR STEEL BARS, CARBON, STRESS-RELIEVED COLD-DRAWN, SUBJECT TO MECHANICAL PROPERTY REQUIREMENTS

SA-311/SA-311M

(Identical to ASTM Specification A 311/A 311M-90b except for deletion of 5.1.11 and editorial corrections to Table 1.)

1. Scope

1.1 This specification covers two classes, nine grades, and four conditions of stress-relieved cold-drawn carbon steel bars produced to mechanical property requirements. One class, B, is cold drawn with higher than normal (heavy) drafts to provide higher strength levels, and four grades provide improved machinability.

1.2 Supplementary Requirements, S1 through S6, of an optional nature are provided.

1.3 The values stated in inch-pound units or SI units are to be regarded as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents, therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

E 527 Practice for Numbering Metals and Alloys (UNS)

3. Terminology

3.1 *Definition:*

3.1.1 *stress relieving* — heating to a suitable temperature, holding long enough to reduce residual stresses, and then cooling slowly enough to minimize the development of new residual stresses.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *heavy draft* — Using higher than normal drafts (approximately 10% through 35% reduction), followed by stress relieving, produces higher tensile and yield strengths provided an appropriate composition is used; for example, medium carbon with normal or higher manganese content.

4. Classification

4.1 The bars are furnished in the following classes and grades, and in the conditions shown in 6.4:

4.1.1 *Class A* — Normal-draft cold-drawn and stress-relieved rounds, squares, hexagons, and flats in the following grades:

Grades	UNS Designations
1018	G10180
1035	G10350
1045	G10450
1050	G10500
1541	G15410
1117	G11170
1137	G11370
1141	G11410
1144	G11440

4.1.2 *Class B* — Heavy-draft cold-drawn and stress-relieved rounds and hexagons in the following grades:

Grade	UNS Designations
1045	G10450
1050	G10500
1541	G15410
1141	G11410
1144	G11440

5. Ordering Information

5.1 Orders for material under this specification should include the following information as required to adequately describe the desired material:

5.1.1 Quantity (weight [mass] or number of pieces),

5.1.2 Name of material (carbon steel bars, cold drawn, stress relieved),

5.1.3 Condition (7.4),

5.1.4 Cross-sectional shape,

5.1.5 Size,

5.1.6 Length,

5.1.7 Class and grade,

5.1.8 Report of heat analysis, tensile properties (Section 11),

5.1.9 ASTM designation A 311 or A 311M,

5.1.10 Application,

5.1.11 DELETED,

5.1.12 Supplementary requirements, if any, and

5.1.13 Additional requirements, if any.

NOTE — A typical ordering description is as follows: 10 000 lb carbon steel bars, cold drawn, stress relieved turned and polished, round 2.0 in. (50.8 mm) Diameter, 10 to 12 ft (3048 to 3658 mm) long, Class B, Grade 1050, (UNS G10500), fine grain, test reports required, ASTM A 311/A 311M dated ____, hydraulic cylinder piston rods. [5000 kg carbon steel bars, cold drawn, stress relieved turned and polished round 50 mm diameter, 3050 to 3650 mm long, Class B, Grade 1050 (UNS G10500), fine grain, test reports required, ASTM A 311M dated ____, hydraulic cylinder piston rods.]

6. General Requirements

6.1 Material furnished under this specification shall conform to the requirements of the current edition of Specification A 29/A 29M unless otherwise stated.

7. Materials and Manufacture

7.1 *Melting Practice* — The steel shall be made by one or more of the following primary processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting using electroslag remelting or vacuum arc remelting. Where secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

7.2 *Cold Working:*

7.2.1 Class A bars shall be cold drawn using normal drafting practices.

7.2.2 Class B bars shall be cold drawn using heavy (higher than normal) drafting practices.

7.3 *Thermal Treatment* — After cold drawing, the bars shall be stress relieved at a temperature of not less than 550°F [288°C] to meet the mechanical requirements specified in Table 2.

7.4 *Condition* — The bars shall be furnished in the following cold finish conditions, as specified:

7.4.1 Cold drawn, stress relieved;

7.4.2 Cold drawn, stress relieved, turned, and polished;

7.4.3 Cold drawn, stress relieved, turned, ground, and polished; and

7.4.4 Cold drawn, stress relieved, ground, and polished.

8. Chemical Composition

8.1 *Composition* — The cast or heat analysis shall conform to the chemical composition requirements specified in Table 1 for the grade ordered.

9. Mechanical Properties

9.1 *Requirements* — The bars shall conform to the requirements listed in Table 2.

9.2 *Number of Tests* — At least one tension test shall be made on each lot. A lot shall consist of bars of the same size from the same heat which have been stress relieved in the same stationary furnace charge. For continuous type of treatment, a lot shall consist of 25 tons [25 Mg] or less of the same size of each heat, treated in the same cycle.

9.3 *Specimens* — Tension test specimens shall be taken longitudinally in accordance with and from the locations specified in Test Methods and Definitions A 370.

9.4 *Test Methods* — Tension tests shall be made in accordance with Test Methods and Definitions A 370. The yield strength shall be determined at 0.2% offset or at 0.005 in./in. [0.005 mm/mm] of gage length, total extension under load.

10. Workmanship, Finish, and Appearance

10.1 *Surface Finish* — Unless otherwise specified, the bars shall have a commercial bright smooth surface finish consistent with the cold finishing operations specified in 6.4.

10.2 Bars that are thermal treated after cold finishing may have a discolored or oxidized surface.

10.3 *Oiling* — The bars shall be given a surface coating of oil or other rust inhibitor to protect against rust during shipment.

10.4 *Workmanship* — The bars shall be free of pipe, cracks, and flakes. Within the limits of good manufacturing and inspection practices, the bars shall be free of injurious seams, laps, segregation, or other imperfections that, due to their nature, degree, or extent, will interfere with the use of the material in machining or fabrication of suitable parts.

11. Certification and Test Reports

11.1 A manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the heat analysis and tension test results shall be furnished at the time of shipment (if requested). The report shall include the name of the manufacturer, ASTM designation and year date and revision letter, if any, class and grade, heat number, size, and grain size (if requested).

TABLE 1
CHEMICAL REQUIREMENTS
(CAST OR HEAT ANALYSIS)[A]

UNS Designation	Grade	Carbon, %	Manganese, %	Phosphorus, max %	Sulfur, %
G10180	1018	0.15–0.20	0.60–0.90	0.040	0.050 max
G10350	1035	0.32–0.38	0.60–0.90	0.040	0.050 max
G10450	1045	0.43–0.50	0.60–0.90	0.040	0.050 max
G10500	1050	0.48–0.55	0.60–0.90	0.040	0.050 max
G15410	1541	0.36–0.44	1.35–1.65	0.040	0.050 max
G11170	1117	0.14–0.20	1.00–1.30	0.040	0.08–0.13
G11370	1137	0.32–0.39	1.35–1.65	0.040	0.08–0.13
G11410	1141	0.37–0.45	1.35–1.65	0.040	0.08–0.13
G11440	1144	0.40–0.48	1.35–1.65	0.040	0.24–0.33

[A] The intentional addition of Bi, Se, Te, and Pb is not permitted.

TABLE 2
MECHANICAL REQUIREMENTS

UNS No.	Grade Designation	Diameter, Thickness, or Distance Between Parallel Faces, in. [mm]	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. [50 mm], min, %	Reduction of Area, min, %
		Class A — Normal Draft Cold Drawn and Stress Relieved Annealed				
G10180	1018	Up to 7/8 [20], incl	70 [485]	60 [415]	18	40
		Over 7/8 [20] to 1 1/4 [30], incl	65 [450]	55 [380]	16	40
		Over 1 1/4 [30] to 2 [50], incl	60 [415]	50 [345]	15	35
		Over 2 [50] to 3 [75], incl	55 [380]	45 [310]	15	35
G10350	1035	Up to 7/8 [20], incl	85 [590]	75 [520]	13	35
		Over 7/8 [20] to 1 1/4 [30], incl	80 [550]	70 [485]	12	35
		Over 1 1/4 [30] to 2 [50], incl	75 [520]	65 [450]	12	35
		Over 2 [50] to 3 [75], incl	70 [485]	60 [415]	10	30
G10450	1045	Up to 7/8 [20], incl	95 [655]	85 [585]	12	35
		Over 7/8 [20] to 1 1/4 [30], incl	90 [620]	80 [550]	11	30
		Over 1 1/4 [30] to 2 [50], incl	85 [585]	75 [520]	10	30
		Over 2 [50] to 3 [75], incl	80 [550]	70 [485]	10	30
G10500	1050	Up to 7/8 [20], incl	100 [690]	90 [620]	11	35
and	and	Over 7/8 [20] to 1 1/4 [30], incl	95 [655]	85 [585]	11	30
G15410	1541	Over 1 1/4 [30] to 2 [50], incl	90 [620]	80 [550]	10	30
		Over 2 [50] to 3 [75], incl	85 [585]	75 [520]	10	30
G11170	1117	Up to 7/8 [20], incl	75 [520]	65 [450]	15	40
		Over 7/8 [20] to 1 1/4 [30], incl	70 [485]	60 [415]	15	40
		Over 1 1/4 [30] to 2 [50], incl	65 [450]	55 [380]	13	35
		Over 2 [50] to 3 [75], incl	60 [415]	50 [345]	12	30
G11370	1137	Up to 7/8 [20], incl	95 [655]	90 [620]	11	35
and	and	Over 7/8 [20] to 1 1/4 [30], incl	90 [620]	85 [585]	11	30
G11410	1141	Over 1 1/4 [30] to 2 [50], incl	85 [585]	80 [550]	10	30
		Over 2 [50] to 3 [70], incl	80 [550]	75 [520]	10	30
G11440	1144	Up to 7/8 [20], incl	105 [725]	95 [655]	10	30
		Over 7/8 [20] to 1 1/4 [30], incl	100 [690]	90 [620]	10	30
		Over 1 1/4 [30] to 2 [50], incl	95 [655]	85 [585]	10	25
		Over 2 [50] to 3 [70], incl	90 [620]	80 [550]	10	20
		Over 3 [70] to 4 1/2 [115], incl	85 [585]	75 [520]	10	20
		Class B — Heavy Draft Cold Drawn and Stress Relieved Annealed				
UNS	Grade Designation	In. [mm], Round or Hexagon[A]	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. [50 mm], min, %	Reduction of Area, min, %
G10450	1045	Up to 7/8 [20] incl	115 [795]	100 [690]	10	25
		Over 7/8 [20] to 1 1/4 [30], incl	115 [795]	100 [690]	10	25
		Over 1 1/4 [30] to 2 [50], incl	115 [795]	100 [690]	10	25
		Over 2 [50] to 3 [75], incl	115 [795]	100 [690]	9	25
		Over 3 [75] to 4 [102], incl	105 [725]	90 [620]	7	20
G10500	1050	Up to 7/8 [20], incl	115 [795]	100 [690]	8	25
G15410	1541	Over 7/8 [20] to 1 1/4 [30], incl	115 [795]	100 [690]	8	25
G11410	1141	Over 1 1/4 [30] to 2 [50], incl	115 [795]	100 [690]	8	25
and	and	Over 2 [50] to 3 [75], incl	115 [795]	100 [690]	8	20
G11440	1144	Over 3 [75] to 4 1/2 [115], incl	115 [795]	100 [690]	7	20

[A] Maximum size for hexagons is 1 1/2 in. [40 mm].

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Special Surface

S1.1 When inspection standards more restrictive than visual inspection are required, special surface may be specified.

S2. Restricted Cast or Heat Analysis

S2.1 When required, the purchaser may specify restrictive cast or heat analysis limits on one or more elements. The degree of restriction and the number of elements so restricted are both subject to agreement between the manufacturer and the purchaser.

S3. Restricted Decarburization

S3.1 The purchaser may specify a maximum affected depth of decarburization when required for special applications, subject to agreement between the manufacturer and the purchaser.

S4. Nonmetallic Inclusion Requirements (Microscopical)

S4.1 When nonmetallic inclusion requirements are specified, the samples for testing shall be taken on a longitudinal direction midway between the center and the surface of the material. The area of the sample to be examined should be agreed upon between the purchaser and the manufacturer, and the test specimen should be hardened by heating and quenched before being polished to avoid pits. The rating of the inclusion count should also be agreed upon and be based upon examination at a magnification of 100 diameters. Resulfurized steels are not subject to inclusion ratings.

S5. Restricted Incidental Elements

S5.1 The purchaser may specify limiting maximum requirements for copper, nickel, chromium, or molybdenum subject to agreement between the manufacturer and the purchaser.

S6. Grain Size

S6.1 The steel shall conform to either the coarse austenitic grain size (except as stated in S6.2), or the fine austenitic grain size requirement of Specification A 29/A 29M.

S6.2 Certain elements, or combinations of elements, such as manganese, sulfur, and lead tend to produce grain refinement and it is technically inappropriate to ensure coarse grain size as measured by the McQuaid-Ehn test on high manganese, high sulfur, and leaded steels such as 1144, 1151, and 11L41.

SPECIFICATION FOR GENERAL REQUIREMENTS FOR FLAT-ROLLED STAINLESS AND HEAT-RESISTING STEEL PLATE, SHEET, AND STRIP

SA-480/SA-480M

(Identical with ASTM Specification A 480/A 480M-96 except that certification is mandatory and clarified heat treatment requirements in 12.1.) 98

1. Scope

1.1 This specification covers a group of general requirements that, unless otherwise specified in the purchase order or in an individual specification, shall apply to rolled steel plate, sheet, and strip, under each of the following specifications issued by ASTM: Specifications A 167, A 176, A 240/A 240M, A 263, A 264, A 265, A 666, A 693, A 793, and A 895.

1.2 In case of any conflicting requirements, the requirements of the purchase order, the individual material specification, and this general specification shall prevail in the sequence named.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 This specification and the applicable material specifications are expressed in both inch-pound and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished in inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip

A 176 Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip

A 240/A 240M Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 263 Specification for Corrosion-Resisting Chromium Steel-Clad Plate, Sheet, and Strip

A 264 Specification for Stainless Chromium-Nickel Steel-Clad Plate, Sheet and Strip

A 265 Specification for Nickel and Nickel-Base Alloy-Clad Steel Plate

A 342 Test Methods for Permeability of Feebly Magnetic Materials

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 666 Specification for Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar

A 693 Specification for Precipitation-Hardening Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A 793 Specification for Rolled Floor Plate, Stainless Steel

A 895 Specification for Free-Machining Stainless Steel Plate, Sheet, and Strip

A 923 Test Methods for Detecting Detrimental Intermetallic Phases in Wrought Duplex Austenitic/Ferritic Stainless Steels

E 112 Test Methods for Determining the Average Grain Size
E 140 Hardness Conversion Tables for Metals (Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Rockwell Superficial Hardness, Knoop Hardness, and Scleroscope Hardness)

2.2 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *Military Standards:*
MIL-STD-129 Marking for Shipment and Storage
MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.4 *AIAG Standard:*
B-5 Primary Metals Identification Tag Application Standard

98 **2.5** *ANSI Standard:*
Accredited Standards Committee X12, (ANSI ASC X12)

3. Terminology

3.1 *Definitions:*

3.1.1 Plate, sheet, strip, and cold work as used in this specification apply to the following:

3.1.1.1 *plate* — material $^{3}/_{16}$ in. [5.00 mm] and over in thickness and over 10 in. [250 mm] in width. Finishes for *plate* are actually shown in Section 10.

3.1.1.2 *sheet* — material under $^{3}/_{16}$ in. [5.00 mm] in thickness and 24 in. [600 mm] and over in width. Finishes for *sheet* are actually shown in Section 8.

3.1.1.3 *strip* — cold-rolled material under $^{3}/_{16}$ in. [5.00 mm] in thickness and under 24 in. [600 mm] in width. Finishes are detailed in Section 9 for *strip*, and strip edges in Section 11 for Cold-Rolled Strip.

3.1.1.4 *cold work* — the changing of mechanical properties by work hardening.

4. Ordering Information

98 **4.1** It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (weight and number of pieces),

4.1.2 Name of material (stainless steel),

4.1.3 Condition (hot-rolled, cold-rolled, annealed, heat-treated),

4.1.4 Finish (see Section 8 for Sheet, Section 9 for Strip, and Section 10 for Plates). In the case of polished finishes, specify whether one or both sides are to be polished,

4.1.5 Temper (if the applicable material specification requires this detail),

4.1.6 Form (plate, sheet, or strip),

4.1.7 Dimensions (thickness, width, length),

4.1.7.1 Thickness shall be ordered to decimal or fractional thickness. The use of the gage number is discouraged as being an archaic term of limited usefulness not having general agreement on meaning. The gage number shall not be a basis for rejection. 98

4.1.7.2 Thickness, width, and length, when applicable, should be ordered in the same units, for example, 0.060 in. by 48 in. by 120 in. (1.52 mm by 1219 mm by 3048 mm). 98

4.1.8 Edge, strip only (see Section 11 for Cold-Rolled Strip),

4.1.9 Type, refer to the applicable material specification,

4.1.10 Specification designation and date of issue,

4.1.11 Additions to specification or special requirements,

4.1.12 Restrictions (if desired) on methods for determining yield strength (see appropriate footnote to mechanical properties table of the basic material specification),

4.1.13 Marking requirements (see Section 21),

4.1.14 Preparation for delivery (see Section 21), and

4.1.15 Magnetic permeability test (when required). Refer to Section 16.

NOTE 1 — A typical ordering description is as follows: 200 pieces, stainless steel sheets, 0.060 in. by 48 in. by 120 in., Type 410 No. 2B finish, ASTM A 176-XX.

5. Process

5.1 The steel shall be manufactured/produced by the following or as specified in the applicable material specification.

5.1.1 The steel shall be made by one of the following processes: electric-arc, electric-induction, or other suitable processes.

5.1.2 If a specific type of melting is required by the purchaser, it shall be so specified on the purchase order.

6. Heat Analysis

6.1 An analysis of each heat shall be made by the steel producer to determine the percentages of the elements specified in the applicable material specification. This analysis shall be made from a test sample taken during the pouring of the melt, or from the in-process product later in the manufacturing flow. The chemical composition thus determined shall conform to the applicable material specification.

6.2 Methods and practices relating to chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

6.3 The steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation in a table of chemical requirements within this specification or any specification listed within the scope as being covered by this specification.

7. Product Analysis

7.1 Product analysis (formerly check analysis) may be made by the purchaser to verify the identity of the finished material representing each heat or lot. Such analysis may be made by any of the commonly accepted methods that will positively identify the material.

7.2 The chemical composition determined in accordance with 7.1 shall conform to the limits of the material specification within the tolerances of Table A1.1, unless otherwise specified in the applicable material specification or the purchase order. The allowable variation of a particular element in a single sample for product analysis may be either above or below the specified range. However, percentages must exhibit the same tendencies in all samples; that is, the several determinations of any individual element in a heat may not vary both above and below the specified range.

8. Finish for Sheet

8.1 The types of finish available on sheet products are:

8.1.1 *No. 1 Finish* — Hot-rolled, annealed, and descaled.

8.2.1 *No. 2D Finish* — Cold-rolled, dull finish.

8.1.3 *No. 2B Finish* — Cold-rolled, bright finish.

8.1.3.1 *Bright Annealed Finish* — A bright cold-rolled finish retained by final annealing in a controlled atmosphere furnace.

8.1.4 *No. 3 Finish* — Intermediate polished finish, one or both sides.

8.1.5 *No. 4 Finish* — General purpose polished finish, one or both sides.

8.1.6 *No. 6 Finish* — Dull satin finish, Tampico brushed, one or both sides.

8.1.7 *No. 7 Finish* — High luster finish.

8.1.8 *No. 8 Finish* — Mirror finish.

8.1.9 *TR Finish* — Cold-worked to obtain specified properties.

NOTE 2 — *Explanation of Sheet Finishes:*

No. 1 — This finish is produced by hot rolling to specified thickness followed by annealing and descaling. It is generally used in industrial applications, such as for heat and corrosion resistance, where smoothness of finished is not of particular importance.

No. 2D — Produced on either hand sheet mills or continuous mills by cold rolling to specified thickness, annealing, and descaling. The dull finish may result from the descaling or pickling operation or may be developed by a final light cold-rolled pass on dull rolls. The dull finish is favorable for retention of lubricants on the surface in deep drawing operations. This finish is generally used in forming deep-drawn articles which may be polished after fabrication.

No. 2B — Commonly produced the same as 2D, except that the annealed and descaled sheet receives a final light cold-rolled pass on polished rolls. This is a general purpose cold-rolled finish. It is commonly used for all but exceptionally difficult deep drawing applications. This finish is more readily polished than No. 1 or No. 2D Finish.

Bright Annealed Finish is a bright cold-rolled highly reflective finish retained by final annealing in a controlled atmosphere furnace. The purpose of the atmosphere is to prevent scaling or oxidation during annealing. The atmosphere is usually comprised of either dry hydrogen or a mixture of dry hydrogen and dry nitrogen (sometimes known as dissociated ammonia).

No. 3 — For use as a finish-polished surface or as a semifinished-polished surface when it is required to receive subsequent finishing operations following fabrication. Where sheet or articles made from it will not be subjected to additional finishing or polishing operations, No. 4 finish is recommended.

No. 4 — Widely used for restaurant equipment, kitchen equipment, store fronts, dairy equipment, etc. Following initial grinding with coarser abrasives, sheets are generally finished last with abrasives approximately 120 to 150 grit.

No. 6 — Has a lower reflectivity than No. 4 finish. It is produced by Tampico brushing No. 4 finish sheets in a medium of abrasive and oil. It is used for architectural applications and ornamentation where high luster is undesirable; it is also used effectively to contrast with brighter finishes.

No. 7 — Has a high degree of reflectivity. It is produced by buffing a finely ground surface, but the grit lines are not removed. It is chiefly used for architectural or ornamental purposes.

No. 8 — The most reflective finish that is commonly produced. It is obtained by polishing with successively finer abrasives and buffing extensively with very fine buffing rouges. The surface is essentially free of grit lines from preliminary grinding operations. This finish is most widely used for press plate, as well as for small mirrors and reflectors.

TR Finish — The finish of products resulting from cold-working an annealed and descaled or bright-annealed product sufficiently to obtain mechanical properties higher than that normally obtained. Appearance will vary depending upon the amount of cold work required and the alloy ordered.

8.1.10 Sheets can be produced with one or two sides polished. When polished on one side only, the other side may be rough ground in order to obtain the necessary flatness.

9. Finish for Strip

9.1 The various types of finish procurable on cold-rolled strip products are:

9.1.1 *No. 1 Finish* — Cold-rolled to specified thickness, annealed, and descaled.

9.1.2 *No. 2 Finish* — Same as No. 1 Finish, followed by a final light cold-roll pass, generally on highly polished rolls.

9.1.3 *Bright Annealed Finish* — A bright cold-rolled finish retained by final annealing in a controlled atmosphere furnace.

9.1.4 *TR Finish* — Cold-worked to obtain specified properties.

9.1.5 *Polished Finish* — Stainless steel strip is also available in polished finishes such as No. 3 and No. 4, which are explained in Note 2.

NOTE 3 — *Explanation of Strip Finishes:*

No. 1 — Appearance of this finish varies from dull gray matte finish to a fairly reflective surface, depending largely upon composition. This finish is used for severely drawn or formed parts, as well as for applications where the brighter No. 2 Finish is not required, such as parts for heat resistance.

No. 2 — This finish has a smoother and more reflective surface, the appearance of which varies with composition. This is a general purpose finish, widely used for household and automotive trim, tableware, utensils, trays, etc.

Bright Annealed Finish — See Note 2.

TR Finish — See Note 2.

10. Finish for Plates

10.1 The types of finish available on plates are:

10.1.1 *Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated* — Scale not removed, an intermediate finish. Use of plates in this condition is generally confined to heat-resisting applications. Scale impairs corrosion resistance.

10.1.2 *Hot-Rolled or Cold Rolled, and Annealed or Heat Treated, and Blast Cleaned or Pickled* — Condition and finish commonly preferred for corrosion-resisting and most heat-resisting applications, essentially a No. 1 Finish.

10.1.3 *Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated, and Surface Cleaned and Polished* — Polish finish is generally No. 4 Finish.

10.1.4 *Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated, and Descaled, and Temper Passed* — Smoother finish for specialized applications.

10.1.5 *Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated, and Descaled; and Cold-Rolled, and Annealed or Heat Treated, and Descaled, and Optionally Temper Passed* — Smooth finish with greater freedom from surface imperfections than in 10.1.4.

11. Edges for Cold-Rolled Strip

11.1 The types of edges available on strip products are:

11.1.1 *No. 1 Edge* — A rolled edge, either round or square as specified.

11.1.2 *No. 3 Edge* — An edge produced by slitting.

11.1.3 *No. 5 Edge* — An approximately square edge produced by rolling or filing after slitting.

12. Heat Treatment

12.1 The heat treatments shown in Table A1.2 and described in this section are to be followed unless otherwise specified in the applicable material specifica-

tion. Heat treatment thermal cycles shall be separate from other processing cycles.

12.2 *Austenitic Types:*

12.2.1 The material shall be solution annealed to meet the mechanical property requirements of the applicable material specification unless otherwise stated in the material specification.

12.2.2 Except as indicated in Table A1.2, Series 300, XM-15, S30415, S30815, S31725, S31726, and S32615 austenitic chromium-nickel steels, when specified on the purchase order, shall be capable of meeting the test for resistance to intergranular corrosion specified in 15.2.

12.2.3 For grades stabilized with titanium or columbium, refer to Note 4.

NOTE 4 — Solution-annealing temperatures above 1950°F [1066°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in the stabilized grades, Types 309Cb, 309HCb, 310Cb, 310HCb, 316Ti, 316Cb, 321, 321H, 347, 347H, 348, and 348H. When intergranular corrosion is of concern, the purchaser should specify the corrosion test of 15.2 (to be conducted on sensitized specimens). The manufacturer may, may if necessary, use a lower temperature resolution anneal or a stabilization anneal after a high temperature solution anneal in order to meet corrosion test requirements. Consideration should be given to the corrosive media before using a stabilization anneal at less than 1800°F [982°C], as such treatment may not be equally effective for all media.

12.2.4 For the stabilized H types, it is noted that the heat treatment requirements shown in Table A1.2 differ as a function of whether the material was cold worked or hot finished.

12.2.4.1 As evidence that the materials are adequately solution annealed 309H, 309HCb, 310H, and 310HCb shall exhibit a grain size of six or coarser as determined in accordance with Test Methods E 112.

12.2.5 The chromium-manganese-nickel types (201, 202, S20103, S20400, S20153, S21800, XM-17, XM-18, XM-19, XM-29, and XM-31) shall be solution annealed to meet the mechanical property requirements of the applicable material specification and, to exhibit adequate resistance to intergranular corrosion (see 15.2). For S20161, the heat treatment is specified in Table A1.2.

12.2.5.1 Note that some of these types may contain high carbon content that can adversely affect resistance to intergranular corrosion.

12.3 *Duplex Types* — The duplex types shall be solution annealed in accordance with Table A1.2.

12.4 *Martensitic and Ferritic Types:*

12.4.1 The chromium steels (S32803, 400 Series, S40945, S41045, S41050, S41500, S44400, S44635, S44660, S44700, S44735, S44800, XM-27, and XM-33) shall be heat treated in such a manner as to satisfy all the requirements for mechanical and bending properties specified in the applicable material specification and (except for 400 series, S41050, and S41500) to provide for adequate resistance to intergranular attack.

12.4.2 For S41500, heat to 1750°F [955°C] minimum, air cool to 200°F [93°C] or lower prior to any optional intermediate temper and prior to the final temper. The final temper shall be between 1050°F [566°C] and 1150°F [621°C].

13. Test Specimens

13.1 *Tension Test:*

13.1.1 Tension test specimens shall be taken from finished material and shall be selected in either or both longitudinal and transverse direction. The tension test specimen shall conform to the appropriate sections of Test Methods and Definitions A 370, unless otherwise specified in the applicable material specification or agreed upon by the seller and the purchaser.

13.1.2 The testing speed between the yield strength and the fracture of the specimen shall be conducted at a constant strain rate between $\frac{1}{8}$ in. [3.18 mm] and $\frac{1}{2}$ in. [12.70 mm] inclusive, per inch [25.40 mm] of gage length per minute, or at a crosshead speed that will give a strain rate within this range. For the purposes of this specification, the rate of strain may be determined by a strain-rate pacer, indicator, or controller, or by dividing the unit elongation by the elapsed time from yield strength to fracture.

13.2 *Hardness Test*—Hardness tests may be made on the grip ends of the tension specimens before they are subjected to the tension test.

13.3 *Bend Test:*

13.3.1 Bend test specimens (when required) shall be taken from finished material and shall be selected in the transverse direction or as indicated in the applicable material specification or as agreed upon by the seller and the purchaser. In the case of transverse bend test specimens, the axis of bend shall be parallel to the direction of rolling.

13.3.2 Bend test specimens from sheet and strip product shall be the full thickness of the material and

approximately 1 in. [25.4 mm] in width. The edges of the test specimen may be rounded to a radius equal to one half the specimen thickness.

13.3.3 The width of strip for which bend tests can be made is subject to practical limitations on the length of the bend test specimen. For narrow strip, the following widths can be tested:

Strip Thickness, in. [mm]	Minimum Strip Width and Minimum Specimen Length for Bend Tests, in. [mm]
0.100 [2.5 mm] and under	½ [2.7 mm]
Over 0.100 [2.5 mm] to 0.140 [3.5 mm], excl.	1 [25.4 mm]
0.140 [3.5 mm] and over	1½ [38.1 mm]

Bend test specimens may be of any suitable length over the specified minimum lengths.

13.3.4 Bend test specimens taken from plates shall be in full thickness of the material up to and including ½ in. [12.7 mm] in thickness, of suitable length, and between 1 and 2 in. [25.4 and 50.8 mm] in width. The sheared edges may be removed to a depth of at least ⅛ in. [3.2 mm] and the sides may be smoothed with a file. The corners of the cross section of the specimen may be broken with a file, but no appreciable rounding of the corners may be permitted.

13.3.5 In the case of plates over ½ in. [12.7 mm] in thickness, bend test specimens, machined to 1 in. [25.4 mm] nominal width by ½ in. [12.7 mm] nominal thickness and at least 6 in. [152.4 mm] in length, may be used. One surface, to be the outside surface in bending, shall be the original surface of the plate; however, surface preparation by light grinding is permitted. The edges may be rounded to a $\frac{1}{16}$ in. [1.6 mm] radius. When permitted by agreement between the seller and the purchaser, the cross section may be modified to ½ in. [12.7 mm] nominal square.

13.3.6 In the case of plates over 1 in. [25.4 mm] in thickness, bend tests must be agreed upon between the seller and the purchaser.

13.3.7 The bend test specimen shall withstand cold bending through the angle specified in the applicable material specification without cracking on the outside of the bent portion.

13.4 The bend may be made over a diameter equal to the number of thicknesses of flat stock shown in the applicable material specification or over a single piece of flat stock equal to the number of thicknesses shown in the applicable material specification; or as shown as follows:

13.4.1 Material up to and including ⅜ in. [9.5 mm] in thickness shall be bent over a piece (or pieces) of flat stock that has the same nominal thickness of the material being tested (1T), allowing the test material to form its natural curvature.

13.4.2 Material over ⅜ in. [9.5 mm] and up to and including 1 in. [25.4 mm] in thickness shall be bent over a piece (or pieces) of flat stock equalling two times the thickness of the material being tested (2T), allowing the test material to form its natural curvature.

14. Number of Tests

14.1 Unless otherwise specified by the applicable material specification or by agreement between the seller and the purchaser, the following number of tests are to be performed.

14.1.1 In the case of plate, sheet, and strip produced in coil form, two or more hardness tests (one from each end of the coil); one bend test, when required; one permeability test, when required; and one or more tension tests shall be made on specimens taken from each coil. If the hardness difference between the two ends of the coil exceeds 5 HRB, or equivalent, or if the material is temper rolled, tensile properties must be determined on both coil ends.

14.1.2 In the case of plate, sheet, or strip produced in cut lengths, one tension test; two tension tests if the material is temper rolled (one tension test for single piece lots); one bend test when required, and one or more hardness tests shall be made on each 100 or less pieces of the same heat and nominal thickness rolled separately or continuously and heat treated within the same operating period, either as a lot or continuously.

NOTE 5 — The term continuously, as applied to heat treatment, is meant to describe a heat-treating operation in which one cut length follows another through the furnace. Interspersement of different melts is permissible if they are of approximately the same nominal thickness and are heat treated in the same operating period and under the same conditions (time and temperature).

14.1.3 One intergranular corrosion test, when required, shall be selected from each heat and thickness subjected to the same heat treatment practice. Such specimens may be obtained from specimens selected for mechanical testing.

15. Special Tests

15.1 If other tests that are thought to be pertinent to the intended application of the material covered by the purchase specification are required, the methods and limits shall be agreed upon between the seller and the purchaser and specified on the purchase order.

15.2 *Resistance to Intergranular Corrosion:*

15.2.1 The intergranular corrosion test, Practice E of Practices A 262, is not required unless it is specified on the purchase order. All austenitic chromium-nickel types except the H types are expected to be capable of passing this test. However, it is not necessary to actually run the test unless it is specified on the purchase order. Note that Practices A 262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3% or more molybdenum in their specified composition, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser. When specified, all flat rolled products of the chromium-nickel series (300 series) in thickness up to and including 2 in. [50.8 mm] nominal size shall be capable of passing the intergranular corrosion test in the as-shipped condition. In the case of heavier plates of types other than 304L, 304LN, 309Cb, 310Cb, 316Cb, 316L, 316LN, 316Ti, 317L, 321, 347, 348, S31725, and S31726, the applicability of this test shall be a matter for negotiation between the seller and the purchaser.

15.2.2 The H types are not normally subject to intergranular corrosion tests. However, Practice E of Practices A 262 may be specified for Type 321H when intergranular corrosion is of concern. In this case, the purchaser shall inform the seller and agree upon the requirements and these requirements shall be so stated on the purchase order.

15.2.3 Austenitic chromium-manganese-nickel types (201, 202, XM-17, XM-18, XM-19, XM-29, XM-31, S20400, and S21800) are to be heat treated for intergranular corrosion resistance. When intergranular corrosion tests are required, they shall be as agreed upon between the seller and the purchaser.

15.2.4 Corrosion tests are not normally required for the 400 series types. Lower-carbon corrosion-resistant types (S44400, S44635, S44660, S44700, S44800, S44735, XM-27, and XM-33) are heat treated for resistance to corrosion. For S44400, S44635, S44660, S44700, S44800, S44735, XM-27, and XM-33, intergranular corrosion testing of Practices A 763, Practice X, Y, or Z may be specified as agreed upon between the seller and the purchaser.

15.3 *Detrimental Intermetallic Phases in Duplex Stainless Steels* — The tests for detrimental intermetallic phases in wrought duplex stainless steels, Methods A, B, or C of Test Methods A 923, are not required unless it is specified on the purchase order. All duplex (austenitic-ferritic) types that are listed in Test Methods A 923 are expected to be capable of passing these tests. However, it is not necessary to actually run the tests unless specified on the purchase order. The applicability of these tests to duplex stainless steels not listed in Test Methods A 923 shall be a matter for negotiation between the seller and the purchaser.

16. Test Methods

16.1 The properties enumerated in applicable specifications shall be determined in accordance with the following ASTM standards.

16.1.1 *Tension Tests*—Test Methods and Definitions A 370.

16.1.2 *Brinell Tests*—Test Methods and Definitions A 370.

16.1.3 *Rockwell Hardness*—Test Methods and Definitions A 370.

16.1.4 *Hardness Equivalents*—Tables E 140.

16.1.5 *Intergranular Corrosion (when specified)*—Practices A 262, Practices A 763.

16.1.6 *Permeability Test (when required)*—Test Methods A 342.

17. Retests and Retreatment

17.1 Retests may be made in accordance with the provisions of Test Methods and Definitions A 370.

17.2 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

17.2.1 If the percentage of elongation of any tension specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. [19.1 mm] from the center of the gage length of the 2 in. [50.8 mm] specimen or is outside the middle half of the gage length of an 8 in. [203.2 mm] specimen, as indicated by scribe marks placed on the specimen before testing, a retest shall be allowed.

17.3 If a bend test specimen fails, due to conditions of bending more severe than required by the specification, a retest shall be permitted, either on a duplicate specimen or on a remaining portion of the failed specimen.

17.4 If the results of any test lot are not in conformance with the requirements of the applicable material specification, such lots may be retreated at the option of the producer. The material shall be accepted if the results of retests on retreated material are within the specified requirements.

17.5 If any specimens selected to represent any heat fail to meet any of the test requirements as specified in the applicable material specification, the material represented by such specimens may be reheat-treated and resubmitted for test.

17.6 If the product analysis fails to conform to the specified limits, analysis shall be made on a new sample. The results of this retest shall be within the specified requirements.

18. Permissible Variations in Dimensions and Weight

18.1 *Sheet*—Sheets shall conform to the permissible variations in dimensions specified in Tables A1.3 (A2.1) to A1.12 (A2.10), inclusive.

18.2 *Cold-Rolled Strip*—Cold-rolled strip shall conform to the permissible variations in dimensions specified in Tables A1.13 (A2.11) to A1.17 (A2.15), inclusive.

18.3 *Plates*—Plates shall conform to the permissible variations in dimensions specified in Tables A1.18 (A2.16) to A1.25 (A2.23), inclusive.

19. Workmanship

19.1 The material shall be of uniform quality consistent with good manufacturing and inspection practices. The steel shall have no imperfections of a nature or degree, for the type and quality ordered, that will adversely affect the stamping, forming, machining, or fabrication of finished parts.

19.2 *Sheet, Strip, and Plate*—Sheet, and strip with No. 1 finish and plate with hot-roll anneal or hot-roll anneal and pickle finish may be ground to remove surface imperfections, provided such grinding does not reduce the thickness or width at any point beyond the permissible variations in dimensions. An iron free abrasive wheel shall be used for such grinding and shall be operated at a speed ample to ensure that defective areas are cleanly cut out.

20. Repair of Plate by Welding

20.1 Repair of surface defects of plate, by welding, is permitted unless prohibited by other specifications or purchase order requirements.

20.2 Defect depth shall not exceed $\frac{1}{3}$ of the nominal thickness, and the total area shall not exceed 1% of the plate surface area, unless prior approval from the purchaser is obtained.

20.3 Unacceptable imperfections shall be suitably prepared for welding by grinding or machining. Open clean defects, such as pits or impressions, may not require preparation.

20.4 The welding procedure and the welders or welding operators shall be qualified in accordance with Section IX of the ASME Code.

20.5 The welding consumables shall be suitable with the plate.

20.6 After repair welding, the welded area shall be ground smooth and blended uniformly to the surrounding surface.

21. Packaging, Marking, and Loading

21.1 *For Commercial Procurement:*

21.1.1 *Marking*—Unless otherwise specified in the applicable material specification or the purchase order, marking shall be conducted as follows:

21.1.1.1 Sheet, strip, and plate shall be marked on one face, in the location indicated below with the specification designation number, type of steel, material identification number, and the name or mark of the manufacturer. The characters shall be of such size as to be clearly legible. The marking shall be sufficiently stable to withstand normal handling. Unless otherwise specified by the purchaser, the marking, at the producer's option, may be done with (a) marking fluid (if a specific maximum impurity limit of designated elements in the marking fluid is required by the purchaser, it shall be so stated on the purchase order), (b) low-stress blunt-nosed continuous or low-stress blunt-nosed-interrupted-dot die stamp, (c) a vibratory tool with a minimum tip radius of 0.005 in. [0.1 mm], or (d) electro-chemical etching.

21.1.1.2 Flat sheet, strip in cut lengths, and plate shall be marked in two places near the ends or may be continuously line marked along one edge.

21.1.1.3 Sheet, strip, and plate in coil form shall be marked near the outside end of the coil. The inside of the coil shall also be marked or shall have a tag or label attached and marked with the information of 21.1.1.1.

21.1.1.4 Material less than ¼ in. [6.4 mm] in thickness shall not be marked with die stamps.

21.1.1.5 The manufacturer's test identification number shall be legibly stamped on each test specimen, if to be shipped to the customer.

21.1.1.6 Material that conforms completely with the requirements of two types of steel within the ordering specification may be marked as both types of steel provided that the manufacturer is certifying the material as meeting the requirements of each of the types of steel. Such marking, if used, may be part of the same marking as used for a single type of steel, or may be a separate but similar marking immediately adjacent to the marking used for a single type of steel.

21.1.1.7 The AIAG primary metals identification tag (AIA B-5) may be used as an auxiliary method of identification in cases where a bar-coded identification tag is desired. Use of this method shall be by agreement between purchaser and supplier.

21.1.2 *Packaging and Loading*—Unless otherwise specified in the applicable material specification or the purchase order, packaging and loading shall be in accordance with the procedures recommended by Practices A 700.

21.2 *For U.S. Government Procurement:*

21.2.1 When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

21.2.2 When specified in the contract or order, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract or order.

22. Inspection

22.1 Inspection of the material by the purchaser's representative at the producing plant shall be made as agreed upon between the purchaser and the seller as part of the purchase order.

22.2 Unless otherwise specified in the contract or purchase order: (*1*) the seller is responsible for the performance of all the inspection and test requirements in this specification, (*2*) the seller may use his own or other suitable facilities for the performance of the inspection and testing, and (*3*) the purchaser shall have the right to perform any of the inspections and tests set forth in this specification. The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with the specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer.

23. Rejection

23.1 Unless otherwise specified, any rejection based on tests made in accordance with this specification shall be reported to the seller within 60 working days from the receipt of the material by the purchaser.

23.2 Material that shows injurious imperfections as described in Section 19 subsequent to its acceptance at the purchaser's works will be rejected and the seller shall be notified.

24. Rehearing

24.1 Samples tested in accordance with this specification that represent rejected material shall be retained for 3 weeks from the date of the notification to the seller of the rejection. In case of dissatisfaction with the results of the test, the seller may make claim for a rehearing within that time.

25. Material Test Report and Certification

25.1 A report of the results of all tests required by the applicable material specification shall be supplied to the purchaser. The report shall include a certification that the material was manufactured, sampled, tested, and inspected in accordance with requirements of the material specification and has been found to meet those requirements.

25.2 A signature is not required on the report. However, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

25.3 Copies of the original manufacturer's test report and certification shall be included with any subsequent test report.

ANNEXES

(Mandatory Information)

A1. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC.—INCH-POUND UNITS

A1.1 Listed in Annex A1 are tables showing the permissible variations in dimensions expressed in inch-pound units of measurement.

TABLE A1.1
CHEMICAL REQUIREMENTS (PRODUCT ANALYSIS TOLERANCES)[A]

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit	Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	to 0.010, incl	0.002	Titanium	to 1.00, incl	0.05
	over 0.010 to 0.030, incl	0.005		over 1.00 to 3.00, incl	0.07
	over 0.030 to 0.20, incl	0.01			
	over 0.20 to 0.60, incl	0.02	Cobalt	over 0.05 to 0.50, incl	0.01[B]
	over 0.60 to 1.20, incl	0.03		over 0.50 to 2.00, incl	0.02
				over 2.00 to 5.00, incl	0.05
Manganese	to 1.00, incl	0.03			
	over 1.00 to 3.00, incl	0.04	Columbium plus tantalum	to 1.50, incl	0.05
	over 3.00 to 6.00, incl	0.05			
	over 6.00 to 10.00, incl	0.06			
	over 10.00 to 15.00, incl	0.10			
	over 15.00 to 20.00, incl	0.15	Tantalum	to 0.10, incl	0.02
Phosphorus	to 0.040, incl	0.005	Copper	to 0.50, incl	0.03
	over 0.040 to 0.20, incl	0.010		over 0.50 to 1.00, incl	0.05
				over 1.00 to 3.00, incl	0.10
Sulfur	to 0.040, incl	0.005		over 3.00 to 5.00, incl	0.15
	over 0.040 to 0.20, incl	0.010		over 5.00 to 10.00, incl	0.20
	over 0.20 to 0.50, incl	0.020			
			Aluminum	to 0.15, incl	−0.005, +0.01
Silicon	to 1.00, incl	0.05		over 0.15 to 0.50, incl	0.05
	over 1.00 to 3.00, incl	0.10		over 0.50 to 2.00, incl	0.10
	over 3.00 to 6.00, incl	0.15			
Chromium	over 4.00 to 10.00, incl	0.10			
	over 10.00 to 15.00, incl	0.15	Nitrogen	to 0.02, incl	0.005
	over 15.00 to 20.00, incl	0.20		over 0.02 to 0.19, incl	0.01
	over 20.00 to 30.00, incl	0.25		over 0.19 to 0.25, incl	0.02
				over 0.25 to 0.35, incl	0.03
Nickel	to 1.00, incl	0.03		over 0.35 to 0.45, incl	0.04
	over 1.00 to 5.00, incl	0.07		over 0.45 to 0.55, incl	0.05
	over 5.00 to 10.0, incl	0.10	Tungsten	to 1.00, incl	0.03
	over 10.00 to 20.00, incl	0.15		over 1.00 to 2.00, incl	0.05
	over 20.00 to 30.00, incl	0.20			
			Vanadium	to 0.50, incl	0.03
Molybdenum	over 0.20 to 0.60, incl	0.03		over 0.50 to 1.50, incl	0.05
	over 0.60 to 2.00, incl	0.05			
	over 2.00 to 8.00, incl	0.10	Selenium	all	0.03

[A] This table does not apply to heat analysis.
[B] Product analysis limits for cobalt under 0.05% have not been established, and the manufacturer should be consulted for those limits.

TABLE A1.2
HEAT TREATMENT REQUIREMENTS

Designation/Type	Temperature	Cooling/ Testing Requirements
Austenitic (Chromium-Nickel) (Chromium-Nickel-Manganese)		
All Cr-Ni steels except as listed below	1900°F [1040°C] minimum	[A]
302, S30215, S30452, S30615, 308, 309, 309Cb, 310, 310Cb, S32615, S33228, S38100	1900°F [1040°C] minimum	[B]
304H, 309H, 310H, 316H	1900°F [1040°C] minimum	[B]
309HCb, 310HCb, 321H, 347H, 348H		
Cold Worked	2000°F [1095°C] minimum	[B]
Hot Finished	1925°F [1050°C] minimum	[B]
N08367	2025°F minimum	[B]
N08904	2000°F [1095°C] minimum	[B]
N08926	2010°F [1100°C] minimum	[B]
S20161	1900° to 2000°F [1040° to 1095°C]	[B]
S30600, S30601	2010° to 2140°F [1100° to 1170°C]	[B]
S31254, S32654	2100°F [1150°C] minimum	[B]
S33228	2050 to 2160°F [1120° to 1180°C]	[B]
S34565	2050° to 2140°F [1120° to 1170°C]	[B]
S35315	2010°F [1100°C] minimum	[B]
Duplex (Austenitic-Ferritic)		
S31200	1900°F [1040°C] minimum	[B]
S31260	1870° to 2010°F [1020° to 1100°C]	[B]
S31803	1900°F [1040°C] minimum	[B]
S32304	1800°F [980°C] minimum	[B]
S32550	1900°F [1040°C] minimum	[B]
S32750	1880° to 2060°F [1025° to 1125°C]	[B]
S32760	2010°F [1100°C] minimum	[B]
S32900	1750° ± 25°F [955° ± 15°C]	[B]
S32950	1850° ± 25°F [1010° ± 15°C]	[B]

[A] Quenched in water or rapidly cooled by other means at a rate sufficient to prevent reprecipitation of carbides, as demonstrable by the capability of passing the test for resistance to intergranular corrosion specified in 15.2.

[B] Quenched in water or rapidly cooled by other means.

TABLE A1.3
PERMISSIBLE VARIATIONS IN THICKNESS FOR HOT-ROLLED SHEETS IN CUT LENGTHS, COLD-ROLLED SHEET IN CUT LENGTHS AND COILS

Specified Thickness,[A] in. [mm]	Permissible Variations, Over and Under[B]	
	in.	mm
Over 0.145 [3.68] to less than 3/16 [4.76]	0.014	0.36
Over 0.130 [3.30] to 0.145 [3.68], incl	0.012	0.30
Over 0.114 [2.90] to 0.130 [3.30], incl	0.010	0.25
Over 0.098 [2.49] to 0.114 [2.90], incl	0.009	0.23
Over 0.083 [2.11] to 0.098 [2.49], incl	0.008	0.20
Over 0.072 [1.83] to 0.083 [2.11], incl	0.007	0.18
Over 0.058 [1.47] to 0.072 [1.83], incl	0.006	0.15
Over 0.040 [1.02] to 0.058 [1.47], incl	0.005	0.13
Over 0.026 [0.66] to 0.040 [1.02], incl	0.004	0.10
Over 0.016 [0.41] to 0.026 [0.66], incl	0.003	0.08
Over 0.007 [0.18] to 0.016 [0.41], incl	0.002	0.05
Over 0.005 [0.13] to 0.007 [0.18], incl	0.0015	0.04
0.005 [0.13]	0.001	0.03

[A] Thickness measurements are taken at least 3/8 in. [9.52 mm] from the edge of the sheet.

[B] Cold-rolled sheets in cut lengths and coils are produced in some type numbers and some widths and thickness to tolerances less than those shown in the table.

TABLE A1.4
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR HOT-ROLLED AND COLD-ROLLED RESQUARED SHEETS (STRETCHER LEVELED STANDARD OF FLATNESS)

Note—Polished sheets with Finishes No. 4 and higher are produced to tolerances given in this table.

Specified Dimensions, in. [mm]	Tolerances		
	Over		Under
	in.	mm	
For thicknesses under 0.131 [3.33]:			
Widths up to 48 [1219] excl	1/16	1.59	0
Widths 48 [1219] and over	1/8	3.18	0
Lengths up to 120 [3048] excl	1/16	1.59	0
Lengths 120 [3048] and over	1/8	3.18	0
For thicknesses 0.131 [3.33] and over:			
All widths and lengths	1/4	6.35	0

TABLE A1.5
PERMISSIBLE VARIATIONS IN WEIGHT FOR HOT-ROLLED AND COLD-ROLLED SHEETS

Any item of five sheets or less, or any item estimated to weigh 200 lb [90.72 kg] or less may actually weigh as much as 10% over the theoretical weight	weigh 200 lb [90.72 kg] or less
Any item of more than five sheets and estimated to weigh more than 200 lb [90.72 kg], may actually weigh as much as 7 1/2% over the theoretical weight	weigh more than 200 lb [90.72 kg]
Chromium-manganese-nickel	40.7 lb/ft^2 · in. thickness [7.82 kg/m^2 · mm thick]
Chromium-nickel	42.0 lb/ft^2 · in. thickness [8.07 kg/m^2 · mm thick]
Chromium	41.2 lb/ft^2 · in. thickness [7.92 kg/m^2 · mm thick]

TABLE A1.6
PERMISSIBLE VARIATIONS IN WIDTH FOR HOT-ROLLED AND COLD-ROLLED SHEETS NOT RESQUARED AND COLD-ROLLED COILS

Specified Thickness, in. [mm]	Tolerances for Specified Width, in. [mm]	
	24 [610] to 48 [1219], excl	48 [1219] and Over
Less than 3/16 [4.76]	1/16 [1.59] over, 0 under	1/8 [3.18] over, 0 under

TABLE A1.7
PERMISSIBLE VARIATIONS IN LENGTH FOR HOT-ROLLED AND COLD-ROLLED SHEETS NOT RESQUARED

Length, ft [mm]	Tolerances, in. [mm]
Up to 10 [3048], incl	1/4 [6.35] over, 0
Over 10 [3048] to 20 [6096], incl	1/2 [12.70] over, 0 under

TABLE A1.8
PERMISSIBLE VARIATIONS IN CAMBER FOR HOT-ROLLED AND COLD-ROLLED SHEETS NOT RESQUARED AND COLD-ROLLED COILS[A]

Specified Width, in. [mm]	Tolerance per Unit Length of Any 8 ft [2438 mm], in. [mm]
24 [610] to 36 [914], incl	1/8 [3.18]
Over 36 [914]	3/32 [2.38]

[A] Camber is the greatest deviation of a side edge from a straight line and measurement is taken by placing an 8 ft [2438 mm] straightedge on the concave side and measuring the greatest distance between the sheet edge and the straightedge.

TABLE A1.9
PERMISSIBLE VARIATIONS IN FLATNESS FOR HOT-ROLLED AND COLD-ROLLED SHEETS SPECIFIED TO STRETCHER-LEVELED STANDARD OF FLATNESS (NOT INCLUDING HARD TEMPERS OF 2XX AND 3XX SERIES)

Specified Thickness, in. [mm]	Width, in. [mm]	Length, in. [mm]	Flatness Tolerance,[A] in. [mm]
Under 3/16 [4.76]	to 48 [1219], incl	to 96 [2438], incl	1/8 [3.18]
Under 3/16 [4.76]	to 48 [1219], incl	over 96 [2438]	1/4 [6.35]
Under 3/16 [4.76]	over 48 [1219]	to 96 [2438], incl	1/4 [6.35]
Under 3/16 [4.76]	over 48 [1219]	over 96 [2438]	1/4 [6.35]

[A] Maximum deviation from a horizontal flat surface.

TABLE A1.10
PERMISSIBLE VARIATIONS IN FLATNESS FOR HOT-ROLLED AND COLD-ROLLED SHEETS NOT SPECIFIED TO STRETCHER-LEVELED STANDARD OF FLATNESS (NOT INCLUDING HARD TEMPERS OF 2XX AND 3XX SERIES, DEAD-SOFT SHEETS AND DEEP-DRAWING SHEETS)

Specified Thickness, in. [mm]	Width, in. [mm]	Flatness Tolerance,[A] in. [mm]
0.062 [1.57] and over	to 60 [1524], incl	1/2 [12.70]
	over 60 [1524] to 72 [1829], incl	3/4 [19.05]
	over 72 [1829]	1 [25.40]
Under 0.062 [1.57]	to 36 [914], incl	1/2 [12.70]
	over 36 [914] to 60 [1524], incl	3/4 [19.05]
	over 60 [1524]	1 [25.40]

[A] Maximum deviation from a horizontal flat surface.

TABLE A1.11
PERMISSIBLE VARIATIONS IN FLATNESS FOR COLD-ROLLED SHEETS OF 2XX AND 3XX SERIES SPECIFIED TO 1/4 AND 1/2 HARD TEMPERS

Specified Thickness, in. [mm]	Width, in. [mm]	Flatness Tolerance,[A] in. [mm]	
		1/4 Hard	1/2 Hard
0.016 [0.41] and under	24 [610] to 36 [914], excl	1/2 [12.70]	3/4 [19.05]
Over 0.016 [0.41] to 0.030 [0.76], incl		5/8 [15.88]	7/8 [22.22]
Over 0.030 [0.76]		3/4 [19.05]	7/8 [22.22]
0.16 [0.41] and under		5/8 [15.88]	1 [25.40]
Over 0.016 [0.41] to 0.030 [0.76], incl	36 [914] to 48 [1219], incl	3/4 [19.05]	1 1/8 [28.58]
Over 0.030 [0.76]		1 [25.40]	1 1/8 [28.58]

[A] Maximum deviation from a horizontal flat surface.

TABLE A1.12
PERMISSIBLE VARIATIONS IN DIAMETER FOR HOT-ROLLED AND COLD-ROLLED SHEETS, SHEARED CIRCLES

Specified Thickness, in. [mm]	Tolerance Over Specified Diameter (No Tolerance Under), in. [mm]		
	Diameters Under 30 in. [762]	Diameters 30 [762] to 48 in. [1219]	Diameters Over 48 in. [1219]
0.0972 [2.46] and thicker	1/8 [3.18]	3/16 [4.76]	1/4 [6.35]
0.0971 [2.46] to 0.0568 [1.45], incl	3/32 [2.38]	5/32 [3.97]	7/32 [5.56]
0.0567 [1.45] and thinner	1/16 [1.59]	1/8 [3.18]	3/16 [4.76]

TABLE A1.13
PERMISSIBLE VARIATIONS IN THICKNESS FOR COLD-ROLLED STRIP IN COILS AND CUT LENGTHS

Note 1 — Thickness measurements are taken at least 3/8 in. [9.52 mm] in from the edge of the strip, except on widths less than 1 in. [25.4 mm] the measurements should be taken at least 1/8 in. [3.18 mm] from the strip edge.

Note 2 — The tolerance in this table include crown tolerances.

Specified Thickness, in. [mm]	Thickness Tolerances, for the Thickness and Widths Given, Over and Under, in. [mm]		
	Width, in. [mm]		
	3/16 [4.76] to 6 [152], incl	Over 6 [152] to 12 [305], incl	Over 12 [305] to 24 [610], excl
	Thickness Tolerances[A]		
0.005 [0.13] to 0.010 [0.25], incl	10%	10%	10%
Over 0.010 [0.25] to 0.011 [0.28], incl	0.0015 [0.04]	0.0015 [0.04]	0.0015 [0.04]
Over 0.011 [0.28] to 0.013 [0.33], incl	0.0015 [0.04]	0.0015 [0.04]	0.002 [0.05]
Over 0.013 [0.33] to 0.017 [0.43], incl	0.0015 [0.04]	0.002 [0.05]	0.002 [0.05]
Over 0.017 [0.43] to 0.020 [0.51], incl	0.0015 [0.04]	0.002 [0.05]	0.0025 [0.06]
Over 0.020 [0.51] to 0.029 [0.74], incl	0.002 [0.05]	0.0025 [0.06]	0.0025 [0.06]
Over 0.029 [0.74] to 0.035 [0.89], incl	0.002 [0.05]	0.003 [0.08]	0.003 [0.08]
Over 0.035 [0.89] to 0.050 [1.27], incl	0.0025 [0.06]	0.0035 [0.09]	0.0035 [0.09]
Over 0.050 [1.27] to 0.069 [1.75], incl	0.003 [0.08]	0.0035 [0.09]	0.0035 [0.09]
Over 0.069 [1.75] to 0.100 [2.54], incl	0.003 [0.08]	0.004 [0.10]	0.005 [0.13]
Over 0.100 [2.54] to 0.125 [2.98], incl	0.004 [0.10]	0.0045 [0.11]	0.005 [0.13]
Over 0.125 [2.98] to 0.161 [4.09], incl	0.0045 [0.11]	0.0045 [0.11]	0.005 [0.13]
Over 0.161 [4.09] to under 3/16 [4.76]	0.005 [0.13]	0.005 [0.13]	0.006 [0.15]

[A] Thickness tolerances given in in. [mm] unless otherwise indicated.

TABLE A1.14
PERMISSIBLE VARIATIONS IN WIDTH FOR COLD-ROLLED STRIP IN COILS AND CUT LENGTHS FOR EDGE NOS. 1 AND 5

Specified Edge No.	Width, in. [mm]	Thickness, in. [mm]	Width Tolerance for Thickness and Width Given, in. [mm]	
			Over	Under
1 and 5	9/32 [7.14] and under	1/16 [1.59] and under	0.005 [0.13]	0.005 [0.13]
1 and 5	over 9/32 [7.14] to 3/4 [19.05], incl	3/32 [2.38] and under	0.005 [0.13]	0.005 [0.13]
1 and 5	over 3/4 [19.05] to 5 [127], incl	1/8 [3.18] and under	0.005 [0.13]	0.005 [0.13]
5	over 5 [127.00] to 9 [228.60], incl	1/8 [3.18] to 0.008 [0.20], incl	0.010 [0.25]	0.010 [0.25]
5	over 9 [228.60] to 20 [508.00], incl	0.105 [2.67] to 0.015 [0.38]	0.010 [0.25]	0.010 [0.25]
5	over 20 [508.00]	0.080 [2.03] to 0.023 [0.58]	0.015 [0.38]	0.015 [0.38]

TABLE A1.15
PERMISSIBLE VARIATIONS IN WIDTH FOR COLD-ROLLED STRIP IN COILS AND CUT LENGTHS FOR EDGE NO. 3

Specified Thickness, in. [mm]	Width Tolerance, Over and Under, for Thickness and Width Given, in. [mm]					
	Under 1/2 [12.70] to 3/16 [4.76], incl	1/2 [12.70] to 6 [152.40], incl	Over 6 [152.40] to 9 [228.60], incl	Over 9 [228.60] to 12 [304.80], incl	Over 12 [304.80] to 20 [508.00], incl	Over 20 [508.00] to 24 [609.60], incl
Under 3/16 [4.76] to 0.161 [4.09], incl	. . .	0.016 [0.41]	0.020 [0.51]	0.020 [0.51]	0.031 [0.79]	0.031 [0.79]
0.160 [4.06] to 0.100 [2.54], incl	0.010 [0.25]	0.010 [0.25]	0.016 [0.41]	0.016 [0.41]	0.020 [0.51]	0.020 [0.51]
0.099 [2.51] to 0.069 [1.75], incl	0.008 [0.20]	0.008 [0.20]	0.010 [0.25]	0.010 [0.25]	0.016 [0.41]	0.020 [0.51]
0.068 [1.73] and under	0.005 [0.13]	0.005 [0.13]	0.005 [0.13]	0.010 [0.25]	0.016 [0.41]	0.020 [0.51]

TABLE A1.16
PERMISSIBLE VARIATIONS IN LENGTH FOR COLD-ROLLED STRIP IN CUT LENGTHS

Specified Length, ft [mm]	Tolerance Over Specified Length (No Tolerance Under), in. [mm]
To 5 [1524], incl	3/8 [9.52]
Over 5 [1524] to 10 [3048], incl	1/2 [12.70]
Over 10 [3048] to 20 [6096], incl	5/8 [15.88]

TABLE A1.17
PERMISSIBLE VARIATIONS IN CAMBER FOR COLD-ROLLED STRIP IN COILS AND CUT LENGTHS[A]

Specified Width, in. [mm]	Tolerance per Unit Length of Any 8ft [2438 mm], in. [mm]
To 1 1/2 [38.10], incl	1/2 [12.70]
Over 1 1/2 [38.10] to 24 [609.60], excl	1/4 [6.35]

[A] Camber is the deviation of a side edge from a straight line and measurement is taken by placing an 8 ft [2438 mm] straightedge on the concave side and measuring the greatest distance between the strip edge and the straightedge.

TABLE A1.18
PERMISSIBLE VARIATIONS IN THICKNESS FOR PLATES[A,B]

Specified Thickness, in. [mm]	Width, in. [mm]			
	To 84 [2134], incl	Over 84 [2134] to 120 [3048], incl	Over 120 [3048] to 144 [3658], incl	Over 144 [3658]
	Tolerance Over Specified Thickness,[C] in. [mm]			
3/16 [4.76] to 3/8 [9.52], excl	0.045 [1.14]	0.050 [1.27]	. . .	. . .
3/8 [9.52] to 3/4 [19.05], excl	0.055 [1.40]	0.060 [1.52]	0.075 [1.90]	0.090 [2.29]
3/4 [19.05] to 1 [25.40], excl	0.060 [1.52]	0.065 [1.65]	0.085 [2.16]	0.100 [2.54]
1 [25.40] to 2 [50.80], excl	0.070 [1.78]	0.075 [1.90]	0.095 [2.41]	0.115 [2.92]
2 [50.80] to 3 [76.20], excl	0.125 [3.18]	0.150 [3.81]	0.175 [4.44]	0.200 [5.08]
3 [76.20] to 4 [101.6], excl	0.175 [4.44]	0.210 [5.33]	0.245 [6.22]	0.280 [7.11]
4 [101.6] to 6 [152.4], excl	0.250 [6.35]	0.300 [7.62]	0.350 [8.89]	0.400 [10.16]
6 [152.4] to 8 [203.2], excl	0.350 [8.89]	0.420 [10.67]	0.490 [12.45]	0.560 [14.22]
8 [203.2] to 10 [254.0], excl	0.450 [11.43]	0.540 [13.72]	0.630 [16.00]	. . .

[A] Thickness is measured along the longitudinal edges of the plate at least 3/8 in. [9.52 mm], but not more than 3 in. [76.20 mm], from the edge.
[B] For plates up to 10 in. [254.0 mm], incl, in thickness, the tolerance under the specified thickness is 0.010 in. [0.25 mm].
[C] For circles, the over thickness tolerances in this table apply to the diameter of the circle corresponding to the width ranges shown. For plates of irregular shape, the over thickness tolerances apply to the greatest width corresponding to the width ranges shown.

TABLE A1.19
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR RECTANGULAR SHEARED MILL PLATES AND UNIVERSAL MILL PLATES

		Tolerances Over Specified Width and Length for Given Width, Length, and Thickness,[A] in. [mm]					
		Under 3/8 in. [9.52 mm] in Thickness		3/8 [9.52] to 1/2 [12.70 mm] in., incl, in Thickness		Over 1/2 [12.70 mm] to 1 in. [25.40 mm] in Thickness	
Width, in. [mm]	Length, in. [mm]	Width	Length	Width	Length	Width	Length
48 [1219] and under	144 [3658] and under	1/8 [3.18]	3/16 [4.76]	3/16 [4.76]	1/4 [6.35]	5/16 [7.94]	3/8 [9.52]
Over 48 [1219] to 60 [1524], incl		3/16 [4.76]	1/4 [6.35]	1/4 [6.35]	5/16 [7.94]	3/8 [9.52]	7/16 [11.11]
Over 60 [1524] to 84 [2134], incl		1/4 [6.35]	5/16 [7.94]	5/16 [7.94]	3/8 [9.52]	7/16 [11.11]	1/2 [12.70]
Over 84 [2134] to 108 [2743], incl		5/16 [7.94]	3/8 [9.52]	3/8 [9.52]	7/16 [11.11]	1/2 [12.70]	9/16 [14.29]
Over 108 [2743]		3/8 [9.52]	7/16 [11.11]	7/16 [11.11]	1/2 [12.70]	5/8 [15.88]	11/16 [17.46]
48 [1219] and under	over 144 [3658] to 240 [6096]	3/16 [4.76]	3/8 [9.52]	1/4 [6.35]	1/2 [12.70]	5/16 [7.94]	5/8 [15.88]
Over 48 [1219] to 60 [1524], incl		1/4 [6.35]	7/16 [11.11]	5/16 [7.94]	5/8 [15.88]	3/8 [9.52]	3/4 [19.05]
Over 60 [1524] to 84 [2134], incl		3/8 [9.52]	1/2 [12.70]	7/16 [11.11]	11/16 [17.46]	1/2 [12.70]	3/4 [19.05]
Over 84 [2134] to 108 [2743], incl		7/16 [11.11]	9/16 [14.29]	1/2 [12.70]	3/4 [19.05]	5/8 [15.88]	7/8 [22.22]
Over 108 [2743]		1/2 [12.70]	5/8 [15.88]	5/8 [15.88]	7/8 [22.22]	11/16 [17.46]	1 [25.40]
48 [1219] and under	over 240 [6096] to 360 [9144]	1/4 [6.35]	1/2 [12.70]	5/16 [7.94]	5/8 [15.88]	3/8 [9.52]	3/4 [19.05]
Over 48 [1219] to 60 [1524], incl		5/16 [7.94]	5/8 [15.88]	3/8 [9.52]	3/4 [19.05]	1/2 [12.70]	3/4 [19.05]
Over 60 [1524] to 84 [2134], incl		7/16 [11.11]	11/16 [17.46]	1/2 [12.70]	3/4 [19.05]	5/8 [15.88]	7/8 [22.22]
Over 84 [2134] to 108 [2743], incl		9/16 [14.29]	3/4 [19.05]	5/8 [15.88]	7/8 [22.22]	3/4 [19.05]	1 [25.40]
Over 108 [2743]		5/8 [15.88]	7/8 [22.22]	11/16 [17.46]	1 [25.40]	7/8 [22.22]	1 [25.40]
60 [1524] and under	over 360 [9144] to 480 [12192]	7/16 [11.11]	1 1/8 [28.58]	1/2 [12.70]	1 1/4 [31.75]	5/8 [15.88]	1 3/8 [34.92]
Over 60 [1524] to 84 [2134], incl		1/2 [12.70]	1 1/4 [31.75]	5/8 [15.88]	1 3/8 [34.92]	3/4 [19.05]	1 1/2 [38.10]
Over 84 [2134] to 108 [2743], incl		9/16 [14.29]	1 1/4 [31.75]	3/4 [19.05]	1 3/8 [34.92]	7/8 [22.22]	1 1/2 [38.10]
Over 108 [2743]		3/4 [19.05]	1 3/8 [34.92]	7/8 [22.22]	1 1/2 [38.10]	1 [25.40]	1 5/8 [41.28]
60 [1524] and under	over 480 [12192] to 600 [15240]	7/16 [11.11]	1 1/4 [31.75]	1/2 [12.70]	1 1/2 [38.10]	5/8 [15.88]	1 5/8 [41.28]
Over 60 [1524] to 84 [2134], incl		1/2 [12.70]	1 3/8 [34.92]	5/8 [15.88]	1 1/2 [38.10]	3/4 [19.05]	1 5/8 [41.28]
Over 84 [2134] to 108 [2743], incl		5/8 [15.88]	1 3/8 [34.92]	3/4 [19.05]	1 1/2 [38.10]	7/8 [22.22]	1 5/8 [41.28]
Over 108 [2743]		3/4 [19.05]	1 1/2 [38.10]	7/8 [22.22]	1 5/8 [41.28]	1 [25.40]	1 3/4 [44.45]
60 [1524] and under	over 600 [15240]	1/2 [12.70]	1 3/4 [44.45]	5/8 [15.88]	1 7/8 [47.62]	3/4 [19.05]	1 7/8 [47.62]
Over 60 [1524] to 84 [2134], incl		5/8 [15.88]	1 3/4 [44.45]	3/4 [19.05]	1 7/8 [47.62]	7/8 [22.22]	1 7/8 [47.62]
Over 84 [2134] to 108 [2743], incl		5/8 [15.88]	1 3/4 [44.45]	3/4 [19.05]	1 7/8 [47.62]	7/8 [22.22]	1 7/8 [47.62]
Over 108 [2743]		7/8 [22.22]	1 3/4 [44.45]	1 [25.40]	2 [50.80]	1 1/8 [28.58]	2 1/4 [57.15]

[A] The tolerance under specified width and length is 1/4 in. [6.35 mm].

TABLE A1.20
PERMISSIBLE VARIATIONS IN FLATNESS FOR ANNEALED PLATES

NOTE 1—Tolerances in this table apply to plates up to 15 ft [4572 mm] in length, or to any 15 ft [4572 mm] of longer plates.

NOTE 2—If the longer dimension is under 36 in. [914 mm], the tolerance is not greater than 1/4 in. [6.35 mm]

NOTE 3—For plates with specified minimum yield strengths of 35 ksi [240 MPa] or more, the permissible variations are increased to 1 1/2 times the amounts shown below.

	Flatness Tolerance (Deviation from a Horizontal Flat Surface) for Thicknesses and Widths Given, in. [mm]								
	Width, in. [mm]								
Specified Thickness, in. [mm]	48 [1219] or Under	Over 48 [1219] to 60 [1524], excl	60 [1524] to 72 [1829], excl	72 [1829] to 84 [2134], excl	84 [2134] to 96 [2438], excl	96 [2438] to 108 [2743], excl	108 [2743] to 120 [3048], excl	120 [3048] to 144 [3648], excl	144 [3658] and Over
3/16 [4.76] to 1/4 [6.35], excl	3/4 [19.05]	1 1/16 [26.99]	1 1/4 [31.75]	1 3/8 [34.92]	1 5/8 [41.28]	1 5/8 [41.28]	1 7/8 [47.62]	2 [50.80]	. . .
1/4 [6.35] to 3/8 [9.52], excl	11/16 [17.46]	3/4 [19.05]	15/16 [23.81]	1 1/8 [28.58]	1 3/8 [34.92]	1 7/16 [36.51]	1 9/16 [39.69]	1 7/8 [47.62]	. . .
3/8 [9.52] to 1/2 [12.70], excl	1/2 [12.70]	9/16 [14.29]	11/16 [17.46]	3/4 [19.05]	15/16 [23.81]	1 1/8 [28.58]	1 1/4 [31.75]	1 7/16 [36.51]	1 3/4 [44.45]
1/2 [12.70] to 3/4 [19.05], excl	1/2 [12.70]	9/16 [14.29]	5/8 [15.88]	5/8 [15.88]	13/16 [20.64]	1 1/8 [28.58]	1 1/8 [28.58]	1 1/8 [28.58]	1 3/8 [34.92]
3/4 [19.05] to 1 [25.40], excl	1/2 [12.70]	9/16 [14.29]	5/8 [15.88]	5/8 [15.88]	3/4 [19.05]	13/16 [20.64]	15/16 [23.81]	1 [25.40]	1 1/8 [28.58]
1 [25.40] to 1 1/2 [38.10], excl	1/2 [12.70]	9/16 [14.29]	9/16 [14.29]	9/16 [17.46]	11/16 [17.46]	11/16 [17.46]	11/16 [17.46]	3/4 [19.05]	1 [25.40]
1 1/2 [38.10] to 4 [101.60], excl	5/16 [7.94]	3/8 [9.52]	7/16 [11.11]	1/2 [12.70]	5/8 [15.88]	3/4 [19.05]	7/8 [22.22]	1 [25.40]	1 [25.40]
4 [101.60] to 6 [152.40], excl	3/8 [9.52]	7/16 [11.11]	9/16 [14.29]	5/8 [15.88]	3/4 [19.05]	15/16 [23.81]	1 1/8 [28.58]	1 1/4 [31.75]	1 1/4 [31.75]

TABLE A1.21
WAVINESS TOLERANCES FOR PLATES

Note—Waviness denotes the deviation of the top or bottom surface from a horizontal line contacting the surface, when the plate is resting on a flat surface, as measured in an increment of less than 15 ft [4.6 m] of length.

	Number of Waves in 15 ft (4.6 m)							
	1	2	3	4	5	6	7	8
Tolerance, expressed as % of Table 19 Tolerance	100	100	80	70	60	50	40	40

TABLE A1.22
PERMISSIBLE VARIATIONS IN CAMBER FOR SHEARED MILL AND UNIVERSAL MILL PLATES[A]

Maximum camber = 1/8 in. in any 5 ft = 3.18 mm in any 1.524 m

[A] Camber is the deviation of a side edge from a straight line, and measurement is taken by placing a 5 ft straightedge on the concave side and measuring the greatest distance between the plate and the straightedge.

TABLE A1.23
PERMISSIBLE VARIATIONS IN DIAMETER FOR CIRCULAR PLATES

	Tolerance Over Specified Diameter for Given Diameter and Thickness,[A] in. [mm]		
Specified Diameter, in. [mm]	To 3/8 [9.52] in., excl in Thickness	3/8 [9.52] to 5/8 [15.88] in., excl in Thickness	5/8 in. [15.88] and Over in Thickness[B]
To 60 [1524], excl	1/4 [6.35]	3/8 [9.52]	1/2 [12.70]
60 [1524 mm] to 84 [2134 mm], excl	5/16 [7.94]	7/16 [11.11]	9/16 [14.29]
84 [2134 mm] to 108 [2743 mm], excl	3/8 [9.52]	1/2 [12.70]	5/8 [15.88]
108 [2743 mm] to 180 [4572 mm], excl	7/16 [11.11]	9/16 [14.29]	11/16 [17.46]

[A] No tolerance under.

[B] Circular and sketch plates over 5/8 in. [15.88 mm] in thickness are not commonly sheared but are machined or flame cut.

TABLE A1.24
TORCH CUTTING TOLERANCES[A] AND RECOMMENDED CLEANUP ALLOWANCE FOR RECTANGULAR PLATES, CIRCLES, RINGS, AND SKETCHES

	Tolerance, in.		Cleanup Allowance[B] per Edge, in.
Specified Thickness, in.	Outside Dimension	Inside Dimension	
2 and under	+3/8, −0	−3/8, +0	±1/4
Over 2 to 3 incl	+1/2, −0	−1/2, +0	±3/8
Over 3 to 6 incl	+3/4, −0	−3/4, +0	±1/2

[A] Tolerances to apply unless otherwise agreed. Note that for some applications user may wish to specify minus rather than plus tolerance or vice versa.

[B] Recommended cleanup allowance which, unless otherwise specified, will be applied by supplier to purchasers ordered size.

TABLE A1.25
PERMISSIBLE VARIATIONS IN ABRASIVE CUTTING WIDTH AND LENGTH FOR PLATES

	Tolerance over Specified Width and Length[A]	
Specified Thickness, in. [mm]	Width	Length
Up to 1 [25.40], incl	1/8 [3.18]	1/8 [3.18]
1 [25.40] to 2 [50.80], incl	3/16 [4.76]	3/16 [4.76]
2 [50.80] to 3 [76.20], incl	1/4 [6.35]	1/4 [6.35]
3 [76.20] to 4 [101.6], incl[B]	5/16 [7.94]	5/16 [7.94]

[A] The tolerances under specified width and length is 1/8 in. [3.18 mm].

[B] Width and length tolerances for abrasive cut plates over 4 in. [101.6 mm] thick are not included in the table; consult producer.

A2. PERMISSIBLE VARIATIONS IN DIMENSIONS, ETC.—SI UNITS

A2.1 Listed in Annex A2 are tables showing the permissible variations in dimensions expressed in SI units of measurement.

TABLE A2.1
PERMISSIBLE VARIATIONS IN THICKNESS FOR HOT-ROLLED SHEETS IN CUT LENGTHS, COLD-ROLLED SHEETS IN CUT LENGTHS AND COILS

Note 1—Thickness measurements are taken at least 10 mm from the edge of the sheet.

Note 2—Cold rolled sheets in cut lengths and coils are produced in some type numbers and some widths and thicknesses to tolerances less than those shown in the table.

Note 3—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

	Permissible Variations, mm	
Specified Thickness, mm	Over	Under
4.99	0.36	0.36
4.00	0.36	0.36
3.75	0.36	0.36
3.50	0.30	0.30
3.25	0.30	0.30
3.00	0.25	0.25
2.75	0.25	0.25
2.50	0.23	0.23
2.25	0.20	0.20
2.00	0.18	0.18
1.75	0.15	0.15
1.50	0.15	0.15
1.25	0.13	0.13
1.00	0.13	0.13
0.75	0.10	0.10
0.50	0.08	0.08
0.25	0.05	0.05
0.20	0.05	0.05
0.15	0.04	0.04
0.10	0.03	0.03

TABLE A2.2
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR HOT-ROLLED AND COLD-ROLLED RESQUARED SHEETS (STRETCHER-LEVELED STANDARD OF FLATNESS)

Note—Polished sheets with Finishes No. 4 and higher are produced to tolerances given in this table.

Specified Dimensions, mm			Width and Length Tolerance, mm	
Thickness	Width	Length	Over	Under
3.30 and over	All	All	7	0
Under 3.30	Up to 1200	Up to 3000	2	0
	1200 and over	3000 and over	3	0

TABLE A2.3
PERMISSIBLE VARIATIONS IN WEIGHT FOR HOT-ROLLED AND COLD-ROLLED SHEETS

Any item of five sheets or less, and estimated to weigh 100 kg or less, may actually weigh 10% over the theoretical weight	weigh 100 kg or less
Any item of more than five sheets and estimated to weigh more than 100 kg, may actually weigh $7\frac{1}{2}$% over the theoretical weight	weigh more than 100 kg
Chromium-manganese-nickel	7.82 kg/m^2/mm thick
Chromium-nickel	8.07 kg/m^2/mm thick
Chromium	7.92 kg/m^2/mm thick

TABLE A2.4
PERMISSIBLE VARIATIONS IN WIDTH FOR HOT-ROLLED AND COLD-ROLLED SHEETS NOT RESQUARED AND COLD-ROLLED COILS

Specified Dimensions, mm		Tolerance, mm	
Thickness	Width	Over	Under
4.99 and under	1200 and over	4	0
	600 to 1200, excl	2	0

TABLE A2.5
PERMISSIBLE VARIATIONS IN LENGTH FOR HOT-ROLLED AND COLD-ROLLED SHEETS NOT RESQUARED

	Tolerance, mm	
Specified Length, mm	Over	Under
3000 to 6000 incl	13	0
Under 3000	7	0

TABLE A2.6
PERMISSIBLE VARIATIONS IN CAMBER FOR HOT-ROLLED AND COLD-ROLLED SHEETS NOT RESQUARED AND COLD-ROLLED COILS[A]

Specified Width, mm	Tolerance per Unit Length of Any 2400 mm, mm
900 and over	3
600 to 900, excl	4

[A] Camber is the greatest deviation of a side edge from a straight line and measurement is taken by placing an 8 ft [2438 mm] straightedge on the concave side and measuring the greatest distance between the sheet edge and the straightedge.

TABLE A2.7
PERMISSIBLE VARIATIONS IN FLATNESS FOR HOT-ROLLED AND COLD-ROLLED SHEETS SPECIFIED TO STRETCHER-LEVELED STANDARD OF FLATNESS (NOT INCLUDING HARD TEMPERS OF 2XX AND 3XX SERIES)

Specified Dimensions, mm			Flatness Tolerance[A], mm
Thickness	Width	Length	
4.99 and under	1200 and over	2400 and over	7
		to 2400 excl	7
	to 1200, excl	2400 and over	7
		to 2400 excl	4

[A] Maximum deviation from a horizontal flat surface.

TABLE A2.8
PERMISSIBLE VARIATIONS IN FLATNESS FOR HOT-ROLLED AND COLD-ROLLED SHEETS NOT SPECIFIED TO STRETCHER-LEVELED STANDARD OF FLATNESS (NOT INCLUDING HARD TEMPERS OF 2XX AND 3XX SERIES, DEAD-SOFT SHEETS AND DEEP-DRAWING SHEETS)

Specified Dimensions, mm		Flatness Tolerance[A], mm
Thickness	Width	
1.50 and over	1800 and over	26
	1500 to 1800, excl	19
	to 1500, excl	13
Under 1.50	1500 and over	26
	900 to 1500 excl	19
	to 900, excl	13

[A] Maximum deviation from a horizontal flat surface.

TABLE A2.9
PERMISSIBLE VARIATIONS IN FLATNESS FOR COLD-ROLLED SHEETS OF 2XX AND 3XX SERIES SPECIFIED TO 1/4 AND 1/2 HARD TEMPERS

Specified Dimensions, mm		Flatness Tolerance[A], mm	
Thickness	Width	1/4 Hard	1/2 Hard
Over 0.80	600 to 900, excl	13	19
0.04 to 0.80 incl		16	23
0.04 and under		19	23
Over 0.80	900 to 1200, incl	16	26
0.04 to 0.80 incl		19	29
0.04 and under		26	29

[A] Maximum deviation from a horizontal flat surface.

TABLE A2.10
PERMISSIBLE VARIATIONS IN DIAMETER FOR HOT-ROLLED AND COLD-ROLLED SHEETS, SHEARED CIRCLES

Specified Thickness, mm	Tolerance Over Specified Diameter No Tolerance Under		
	Diameters Under 600	Diameters 600 to 1200 incl	Diameters Over 1200
2.50 and thicker	4	5	7
1.50 to 2.50 excl	3	4	6
Under 1.50	2	3	5

TABLE A2.11
PERMISSIBLE VARIATIONS IN THICKNESS FOR COLD-ROLLED STRIP IN COILS AND CUT LENGTHS

Note 1 — Thickness measurements are taken at least 10 mm in from the edge of the strip, except that on widths less than 26 mm, the tolerances are applicable for measurements at all locations.

Note 2 — The tolerances in this table include crown tolerances.

Note 3 — For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

Specified Thickness, mm	Thickness Tolerances[A], for the Thickness and Widths Given, Over and Under, mm		
	Width, mm		
	50 to 150, incl	Over 150 to 300, incl	Over 300 to 600, excl
4.99	0.13	0.13	0.15
4.00	0.13	0.13	0.15
3.00	0.11	0.11	0.13
2.50	0.10	0.11	0.13
2.00	0.08	0.10	0.13
1.75	0.08	0.10	0.13
1.50	0.08	0.09	0.09
1.25	0.08	0.09	0.09
1.00	0.06	0.09	0.09
0.75	0.06	0.09	0.09
0.50	0.05	0.06	0.06
0.25	0.04	0.04	0.05
0.15	10%	10%	10%

[A] Thickness tolerances given in mm unless otherwise indicated.

TABLE A2.12
PERMISSIBLE VARIATIONS IN WIDTH FOR COLD-ROLLED STRIP IN COILS AND CUT LENGTHS FOR EDGE NOS. 1 AND 5

Specified Edge No.	Specified Dimension, mm		Width Tolerance, mm	
	Width	Thickness	Over	Under
5	600 and over	2.00 to 0.60 incl	0.40	0.40
5	300 to 600 excl	2.60 to 0.40 incl	0.25	0.25
5	100 to 300 excl	3.00 to 0.20 incl	0.25	0.25
1 and 5	20 to 100 excl	3.00 and under	0.13	0.13
1 and 5	10 to 20 excl	2.50 and under	0.13	0.13
1 and 5	under 10	1.50 and under	0.13	0.13

TABLE A2.13
PERMISSIBLE VARIATIONS IN WIDTH FOR COLD-ROLLED STRIP IN COILS AND CUT LENGTHS FOR EDGE NO. 3 FOR SPECIFIED THICKNESS OTHER THAN THOSE SHOWN, THE TOLERANCES FOR THE NEXT HIGHER THICKNESS SHALL APPLY.

Specified Thickness, mm	Width Tolerance, Over and Under, for Thickness and Width Given, mm					
	5 to 12 excl	12 to 150 excl	150 to 200 excl	200 to 300 excl	300 to 500 excl	500 to 600 excl
4.99	. . .	0.40	0.50	0.50	0.80	0.80
4.00	0.25	0.25	0.40	0.40	0.50	0.50
2.50	0.20	0.20	0.25	0.25	0.40	0.50
1.75 and under	0.13	0.13	0.13	0.25	0.40	0.50

TABLE A2.14
PERMISSIBLE VARIATIONS IN LENGTH FOR COLD-ROLLED STRIP IN CUT LENGTHS

Specified Length, mm	Tolerance Over Specified Length (No Tolerance Under), mm
To 1500 incl	16
Over 1500 to 3000, incl	13
Over 3000 to 6000, incl	10

TABLE A2.15
PERMISSIBLE VARIATIONS IN CAMBER FOR COLD-ROLLED STRIP IN COILS AND CUT LENGTHS[A]

Specified Width, mm	Tolerance Per Unit Length Of Any 2400 mm
Over 40 to 600, incl	7
to 40, incl	13

[A] Camber is the deviation of a side edge from a straight line and measurement is taken by placing a 2400 mm straightedge on the concave side and measuring the greatest distance between the strip edge and the straightedge.

TABLE A2.16
PERMISSIBLE VARIATIONS IN THICKNESS FOR PLATES[A]

NOTE — For specified thicknesses other than those shown, the tolerances for the next highest thickness shall apply.

Specified Thickness, mm	Width, mm			
	To 2100, excl	2100 to 3000, excl	3000 to 3600, excl	Over 3600
	Tolerance over Specified Thickness,[B] mm			
250	11.45	13.75	16.00	. . .
200	8.96	10.70	12.45	14.25
150	6.35	7.65	8.90	10.15
100	4.45	5.35	6.25	7.10
75	3.20	3.80	4.45	5.10
50	1.80	1.90	2.40	2.95
25	1.55	1.65	2.15	2.55
20	1.40	1.55	1.90	2.30
10	1.15	1.30	. . .	. . .
5	1.15	1.30	. . .	. . .

[A] Thickness is measured along the longitudinal edges of the plate at least $\frac{3}{8}$ in. [9.52 mm], but not more than 3 in. [76.20 mm], from the edge.

[B] For circles, the over thickness tolerances in this table apply to the diameter of the circle corresponding to the width ranges shown. For plates of irregular shape, the over thickness tolerances apply to the greatest width corresponding to the width ranges shown. For plates up to 10 in. [254.0 mm], incl, in thickness, the tolerance under the specified thickness is 0.010 in. [0.25 mm].

TABLE A2.17
PERMISSIBLE VARIATIONS IN WIDTH AND LENGTH FOR RECTANGULAR SHEARED MILL PLATES, TOLERANCES OVER SPECIFIED WIDTH AND LENGTH FOR GIVEN WIDTH, LENGTH, AND THICKNESS[A]

		Under 10 mm in Thickness		10 to 13 mm, incl in Thickness		Over 13 to 26 mm, incl. in Thickness, mm	
Width, mm	Length, mm	Width	Length	Width	Length	Width	Length
2700 and over	15 000 and over	23	45	26	51	29	51
2100 to 2700, excl		16	45	19	48	23	48
1500 to 2100, excl		16	45	19	48	23	48
250 to 1500, excl		13	45	16	48	19	48
2700 and over	12 000 to 5 000, excl	19	38	23	42	26	45
2100 to 2700, excl		16	35	19	38	23	43
1500 to 2100, excl		13	35	16	38	19	42
2500 to 1500, excl		11	32	13	38	16	42
2700 and over	9000 to 1200, excl	19	35	23	38	26	42
2100 to 2700, excl		15	32	19	35	23	38
1500 to 2100, excl		13	32	16	35	19	38
250 and 1500, excl		11	29	13	32	16	35
2700 and over	6000 to 9000, excl	16	23	18	26	23	26
2100 to 2700, excl		15	19	16	23	19	26
1500 to 2100, excl		11	18	13	19	16	23
1200 to 1500, excl		8	16	10	19	13	19
250 to 1200, excl		7	13	8	16	10	19
2700 and over	3600 to 6000, excl	13	16	16	23	18	26
2100 to 2700, excl		11	15	13	19	16	23
1500 to 2100, excl		10	13	11	18	13	19
1200 to 1500, excl		7	11	8	16	10	19
250 to 1200, excl		5	10	7	13	8	16
2700 and over	under 3600	10	11	11	13	16	18
2100 to 2700, excl		8	10	10	11	13	15
1500 to 2100, excl		7	8	8	10	11	13
1200 to 1500, excl		5	7	7	8	10	11
250 to 1200, excl		3	5	5	7	8	10

[A] The tolerance under specified width and length is 7 mm.

TABLE A2.18
PERMISSIBLE FLATNESS VARIATIONS IN ANNEALED PLATES

Note 1 — Tolerances in this table apply to plates up to 4500 mm in length, or to any 4500 mm of longer plates.
Note 2 — If the longer dimension is under 900 mm the tolerance is not greater than 7 mm.
Note 3 — For plates with specified minimum yield strengths of 240 MPa or more, the permissible variations are increased to $1\frac{1}{2}$ times the amounts shown below.
Note 4 — For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

	Flatness Tolerance (Deviation from a Horizontal Flat Surface) for Thickness and Widths Given, mm								
	Width, mm								
Specified Thickness, mm	1200 or under	Over 1200 to 1500, excl	1500 to 1800, excl	1800 to 2100, excl	2100 to 2400, excl	2400 to 2700, excl	2700 to 3000, excl	3000 to 3600, excl	3600 and over
150	7	10	13	15	16	19	22	26	29
100	5	8	10	11	13	15	16	19	23
50	13	15	15	15	18	18	18	19	26
25	13	15	16	16	19	21	24	26	29
20	13	15	16	16	21	29	29	29	35
15	13	15	18	19	24	29	32	37	45
10	16	17	24	29	35	37	40	48	. . .
5	19	19	32	35	42	42	48	51	. . .

TABLE A2.19
WAVINESS TOLERANCES FOR PLATES

Note — Waviness denotes the deviation of the top or bottom surface from a horizontal line contacting the surface, when the plate is resting on a flat surface, as measured in an increment of less than 4.5 m of length.

	Number of Waves in 4.6 m							
	1	2	3	4	5	6	7	8
Tolerance, expressed as % of Table A2.18 Tolerance	100	100	80	70	60	50	40	40

TABLE A2.20
PERMISSIBLE VARIATIONS IN CAMBER FOR SHEARED MILL AND UNIVERSAL MILL PLATES[A]

Maximum camber = 3 mm in any 1500 mm

[A] Camber is the deviation of a side edge from a straight line, and measurement is taken by placing a 1500 mm straightedge on the concave side and measuring the greatest distance between the plate and the straightedge.

TABLE A2.21
PERMISSIBLE VARIATIONS IN DIAMETER FOR CIRCULAR PLATES

Note — For specific diameters other than those shown the tolerance for the next higher diameter shall apply.

	Tolerance Over Specified Diameter for Given Diameter and Thickness,[A] mm		
	Thickness of Plate		
Specified Diameter, mm	To 10 mm, excl	10 mm to 15 mm, excl	15 mm and over
4500	11	15	18
2700	10	13	16
2100	8	11	15
1500 and under	7	10	13

[A] No tolerance under.

TABLE A2.22
TORCH CUTTING TOLERANCES[A] AND RECOMMENDED CLEANUP ALLOWANCE FOR RECTANGULAR PLATES, CIRCLES, RINGS, AND SKETCHES

	Tolerance, mm		Cleanup Allowance[B]
Specified Thickness, mm	Outside Diameter	Inside Diameter	per Edge, mm
51 and under	+10, −0	−10, +0	+6
Over 51 to 76 incl	+13, −0	−13, +0	±10
Over 76 to 152 incl	+19, −0	−19, +0	±13

[A] Tolerances to apply unless otherwise agreed. Note that for some applications user may wish to specify minus rather than plus tolerance or vice versa.

[B] Recommended cleanup allowance which, unless otherwise specified, will be applied by supplier to purchasers ordered size.

TABLE A2.23
PERMISSIBLE VARIATIONS IN ABRASIVE CUTTING WIDTH AND LENGTH FOR PLATES

98

	Tolerance over Specified Width and Length,[A] mm	
Specified Thickness, [mm]	Width	Length
Up to 25, incl	3.2	3.2
25 to 50, incl	4.8	4.8
50 to 75, incl	6.4	6.4
75 to 100, incl[B]	7.9	7.9

[A] The tolerances under specified width and length are 3.2 mm.

[B] Width and length tolerances for abrasive cut plates over 100 mm thick are not included in the table; consult producer.

SPECIFICATION FOR GENERAL REQUIREMENTS FOR STAINLESS STEEL BARS, BILLETS, AND FORGINGS

98

SA-484/SA-484M

(Identical with ASTM Specification A 484/A 484M-94b.)

1. Scope

1.1 This specification covers general requirements that shall apply to stainless wrought steel bars, shapes, forgings, and billets or other semi-finished material (except wire) for forging, under the lastest revision of each of the following ASTM specifications: Specifications A 276, A 314, A 458, A 473, A 477, A 479/A 479M, A 564/A 564M, A 565, A 582/A 582M, A 638/A 638M, A 705/A 705M, and A 831/A 831M.

1.2 In case of conflicting requirements, the individual material specification requirements take precedence.

1.3 General requirements for flat products other than bar are covered in Specification A 480/A 480M.

1.4 General requirements for wire products in coils are covered in Specification A 555/A 555M.

1.5 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as the standard; within the text and tables, the SI units are shown in [brackets]. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.6 Unless the order specifies an "M" designation, the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 276 Specification for Stainless Steel Bars and Shapes

A 314 Specification for Stainless Steel Billets and Bars for Forging

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 458 Specification for Hot-Worked, Hot-Cold-Worked and Cold-Worked Alloy Steel Bars for High Strength at Elevated Temperatures

A 473 Specification for Stainless Steel Forgings

A 477 Specification for Hot-Worked, Hot-Cold-Worked and Cold-Worked Alloy Steel Forgings and Forging Billets for High Strength at Elevated Temperatures

A 479/A 479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 555/A 555M Specification for General Requirements for Stainless and Heat-Resisting Steel Wire and Wire Rods

A 564/A 564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes

A 565 Specification for Martensitic Stainless Steel Bars, Forgings, and Forging Stock for High-Temperature Service

A 582/A 582M Specification for Free-Machining Stainless Steel Bars, Hot-Rolled or Cold-Finished

A 638/A 638M Specification for Precipitation Hardening Iron Base Superalloy Bars, Forgings, and Forging Stock for High-Temperature Service
A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
A 705/A 705M Specification for Age-Hardening Stainless Steel Forgings
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 831/A 831M Specification for Stainless Steel Bars, Billets, and Forgings for Use in Core Components
E 112 Method of Determining the Average Grain Size
E 139 Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

2.2 *Federal Standards:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
Fed. Std. No. 183 Continuous Marking of Iron and Steel Products

2.3 *Military Standards:*
MIL-STD-129 Marking for Shipment and Storage
MIL-STD-163 Preservation of Steel Products for Shipment (Storage and Overseas Shipment)

2.4 *Other Standard:*
Primary Metals Bar Code Standard

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard:*

3.1.1 Bars, shapes, forgings, and billets or other semi-finished material as used in this specification are defined as follows:

3.1.2 *Bars* — Straight lengths that are produced by: hot rolling, forging, extruding, etc. Also included are small shapes with all dimensions under 5 in. [125 mm] and hot-rolled flats up to 10 in. [250 mm] inclusive in width and 0.125 in. [3.00 mm] and over in thickness. Cold-finished bars may be cold drawn, turned, ground or polished and are produced from straight length bars or from straightened and cut rod or wire. Also, bars may be produced by cutting from strip or plate, provided that the long direction of cut bars is parallel to the final rolling direction of the strip or plate.

NOTE — All cold-reduced flat material under 0.1875 in. [5.00 mm] thick is classified as strip if 0.375 in. [9.50 mm] and over in width.

3.1.3 *Forgings* — Parts produced by hot, mechanical shaping of such products as bars and billets, or other semi-finished materials, with hammers, presses, and forging machines.

3.1.4 *Billets* — A semi-finished product (produced on mills or by forging or continuous casting machines) that requires subsequent hot rolling or hot forging. Sizes are generally up to 36 in^2 (230 cm^2) in cross section as squares or rectangles with width less than twice the thickness.

3.1.5 *Blooms* — A semi-finished product (produced on mills or by continuous casting machines) that requires subsequent hot rolling or hot forging. Sizes are generally over 36 $in.^2$ (230 cm^2) in square or rectangular cross sections with width less than twice the thickness. Rectangles with width twice the thickness or greater are classed as slabs or sheet bars.

3.1.6 *Slabs or Sheet Bars* — The products of a primary mill such as blooming, slabbing or sheet bar mills, or continuous or pressure casting machines, which are shipped without further work other than cutting to length or surface conditioning used only for re-rolling into sheet, strip or plate.

3.2 The terms random lengths, multiple lengths, and dead or exact lengths are defined as follows:

3.2.1 *Random Lengths* — A length range of not less than 24 in. [1 m]; for example, 10 to 12 ft [3 to 4 m], 14 to 17 ft [4 to 5 m], or 15 to 20 ft [5 to 6 m].

3.2.2 *Multiple Lengths* — Frequently, fabricating operations will require small unit bar lengths. When such is the case, a single bar containing a predetermined number of such units may be specified. Such a bar is described as a multiple-length bar, and it is common to include in the specified length an allowance of $\frac{1}{4}$ in. [6.5 mm] per unit to ensure cutting the required number of pieces.

3.2.3 *Dead or Exact Length* — Bars specified to dead or exact lengths may be either hot sheared or hot sawed. When greater accuracy in length or freedom from end distortion is required, bars can be machine-cut after machine-straightening. The permissible variations in length for dead or exact length bars are shown in tables at end of this specification.

4. Materials and Manufacture

4.1 The material may be furnished in one of the conditions detailed in the applicable material specification, that is, hot-worked, extruded or forged, forged and machined, annealed, cold-worked or heat-treated (normalized and tempered, or quenched and tempered), etc.

4.2 The types of finish procurable are as follows:

4.2.1 *Hot-Finished Bars* — Hot-finished bars are commonly produced by hot rolling, forging, pressing, extruding, etc. ingots, blooms or billets to final dimensions. Hot-finished bars may be subject to various operations including annealing or other heat treating, cleaning by pickling, blast cleaning or other methods of descaling, rough turning and machine straightening.

4.2.2 *Bars Cut from Strip or Plate* — Two surfaces descaled or pickled, two cut surfaces, except when heat treated after cutting, in which case, all surfaces shall be descaled or pickled.

4.2.3 *Cold-Finished Bars* — Cold-finished bars are produced from hot-finished bars by means of additional operations, for example, cold drawing, centerless grinding, polishing, etc., to provide closer tolerances, improved surface condition or higher strength levels.

4.2.4 *Bars and Billets or Other Semi-Finished Material for Reforging* — Material may be conditioned to remove injurious surface defects provided the depth of conditioning does not exceed that which affects the surface condition or dimensions of the article to be forged from the bar on billet.

4.2.5 *Shapes* — Descaled by machining, grinding, or pickling.

4.2.5.1 Shapes may be subjected to either Class A or Class C surface preparation as specified on the purchase order. Class A consists of grinding for the removal of imperfections of a hazardous nature such as fins, tears, and jagged edges, provided the underweight tolerance is not exceeded and the maximum depth of grinding at any one point does not exceed 10% of the thickness of the section. Class C consists of grinding for the removal of all visible surface imperfections, provided the underweight tolerance is not exceeded and the maximum depth of grinding as any one point does not exceed 10% of the thickness of the section.

4.2.6 *Forgings* — Descaled by machining, blasting or pickling, unless otherwise specified.

5. Chemical Composition

5.1 *Heat or Cast Analysis:*

5.1.1 The chemical analysis of each heat shall be determined in accordance with the applicable material specification and Test Methods, Practices, and Terminology A 751.

5.2 *Product Analysis:*

5.2.1 When required, a product analysis shall be determined in accordance with Test Methods, Practices, and Terminology A 751. The chemical composition thus determined shall conform to the tolerances shown in Table 1.

5.3 The steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade in the referencing product specification, and any of the product specifications within this general specification, for which that element has a specified minimum.

6. Permissible Variations in Dimensions

6.1 Unless otherwise specified on the purchase order, the material shall conform to the permissible variations in dimensions as specified in the following:

6.1.1 *Bars* — Tables 2 through 11.

6.1.2 *Shapes* — Tables 12 through 18 and Figs. 1 and 2.

6.1.3 *Forgings* — As specified in the purchase order, or in prints or sketches accompanying the purchase order.

6.1.4 *Billets or Other Semi-Finished Material for Reforging* — Billets and bars shall conform to the shape and dimensions specified by the purchaser within a permissible variation of ±5%.

7. Workmanship, Finish, and Appearance

7.1 The material shall be of uniform quality consistent with good manufacturing and inspection practices. Imperfections that may be present shall be of such a nature or degree for the type and quality ordered, that they will not adversely affect the forming, machining, or fabrication of finished parts.

8. Lot Size

8.1 A lot for product analysis shall consist of all bars, shapes, and forgings made from the same heat.

8.2 For other tests required by the product specification, a lot shall consist of all bar products of the same size, or forgings weighing less than 1000 lb [500 kg] each, from the same heat, and produced under the same processing conditions. All austenitic, ferritic, and free-

machining stainless steels, as well as martensitic grades when annealed to Condition A and precipitation or age-hardening grades when solution treated, may be heat treated in more than one charge in the same furnace or in several furnaces, utilizing controlled processing and equipment. (See Appendix.) However, when heat treating martensitic stainless steels to Condition T or H and when age hardening the precipitation hardening stainless steels, a lot shall consist of the same size, same heat, and the same heat treat charge in a batch-type furnace or under the same conditions in a continuous furnace.

8.2.1 The forgings weighing from 1000 lb [500 kg] to 5000 lb [2500 kg] each, a lot shall consist of one size classification from each heat and each heat-treating charge. Where continuous heat-treating furnaces are used, a lot shall consist of one size classification from each heat, heat treated in an 8-h (or less) period.

8.2.2 For all classes of forgings weighing from 5000 to 7000 lb [2300 to 3200 kg], each unit shall be considered a lot.

8.2.3 For all classes of forgings weighing more than 7000 lb [3200 kg], each unit shall be considered a double lot, and two tension tests shall be required, one from each end of each forging. In the case of ring forgings, the tension test specimens shall be removed from each of two locations on the periphery, approximately 180° apart, or insofar as practicable from opposite ends of the forging.

9. Number of Tests and Retests

9.1 Unless specified otherwise in the product specification, one sample per heat shall be selected for chemical analysis and one mechanical test sample shall be selected from each lot of bars and shapes and from each lot of forgings. Tension tests of bars and shapes shall be made in the longitudinal direction. Hardness tests on bars shall be conducted midway between the center and surface of the product. Tension tests on forgings shall be prepared from suitable prolongations, or at the option of the supplier, excess forgings may be provided for test. All tests shall conform to the chemical and mechanical requirements of the material specification.

9.2 One intergranular corrosion test, when required, and one grain size test, when required, shall be made from each lot. It is often convenient to obtain test material from the specimen selected for mechanical testing.

9.3 If any test specimen shows defective machining or flaws, it may be discarded and another specimen substituted.

9.4 If the results of any test lot are not in conformance with the requirements of this specification and the applicable product specification, a retest sample of two specimens may be tested to replace each failed specimen of the original sample. If one of the retest specimens fails, the lot shall be rejected.

10. Retreatment

10.1 Where failure of any lot is due to inadequate heat treatment, the material may be reheat-treated and resubmitted for test.

11. Test Methods

11.1 The properties enumerated in applicable specifications shall be determined in accordance with the following ASTM methods:

11.1.1 *Chemical Analysis* — Test Methods, Practices, and Terminology A 751.

11.1.2 *Tension Tests* — Test Methods and Definitions A 370. When identified as such, transverse testing is permitted.

11.1.3 *Stress Rupture* — Practice E 139.

11.1.4 *Brinell Hardness* — Test Methods and Definitions A 370.

11.1.5 *Rockwell Hardness* — Test Methods and Definitions A 370.

11.1.6 *Intergranular Corrosion* (when required) — Practice E of Practices A 262.

11.1.7 *Grain Size* (when required) — Test Methods E 112.

11.1.8 *Charpy V-Notch Impact Test* — Test Methods and Definitions A 370.

12. Inspection

12.1 *For Civilian Procurement* — Inspection of the material shall be as agreed upon between the purchaser and the supplier as part of the purchase contract.

12.2 *For Government Procurement* — Unless otherwise specified in the contract or purchase order: *(1)* the seller is responsible for the performance of all

inspection and test requirements in this specification, *(2)* the seller may use his own or other suitable facilities for the performance of the inspection and testing, and *(3)* the purchaser shall have the right to perform any of the inspection and tests set forth in this specification. The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with the specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly, preferably in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

14. Certification

14.1 A certified report of the test results shall be furnished at the time of shipment. The report shall include the ASTM designation, year date and revision letter, if any.

14.2 A document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

15. Identification of Material

15.1 *For Civilian Procurement:*

15.1.1 Bars and shapes shall be properly marked or tagged with the name of manufacturer, purchaser's name and order number, ASTM specification number, heat number, grade or type, condition, and where appropriate the size, length, and weight. Unless otherwise specified, the method of marking is at the option of the manufacturer, and may be made by hot stamping, cold stamping, painting, or marking tags attached to the bundles, lifts, or boxes.

15.1.2 Forgings shall be legibly die stamped with the manufacturer's symbol or name, material specification number, type, and heat identification. When die stamping is not permitted by the purchaser, electric pencil or electro-etching may be used.

15.2 *For Government Procurement:*

15.2.1 When specified in the contract or order, and for direct procurement by or direct shipment to the Government, marking for shipment, in addition to any requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

15.2.2 For Government procurement by the Defense Supply Agency, bars and shapes shall be continuously marked for identification in accordance with Fed. Std. No. 183.

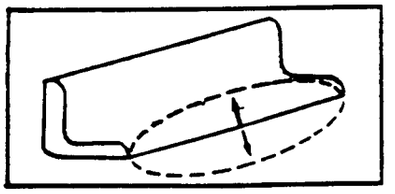
16. Preparation for Delivery

16.1 Unless otherwise specified, the bars and shapes shall be packaged and loaded in accordance with Practices A 700.

16.2 When specified in the contract or order, and for direct procurement by or direct shipment to the Government, when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

17. Keywords

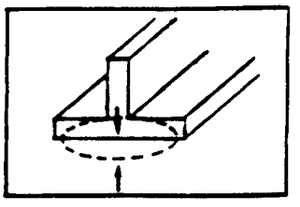
17.1 general delivery requirements; stainless steel bars; stainless steel billets; stainless steel forgings



Camber or bow tolerances shall not exceed 0.025 in. [0.60 mm] × length in ft [m].

NOTE—Camber tolerances for hot finished or extruded shapes camber (or bow) is the greatest deviation of a side from a straight line. Measurement is taken on the concave side of the shapes with a straight edge.

FIG. 1 CAMBER OR BOW TOLERANCES



Allowable deviation from flat is max 0.010 in. [0.25 mm] per 1 in. [25 mm] of width. Maximum deviation on dimensions of less than 1 in. [25 mm] is 0.010 in. [0.250 mm].

NOTE—The transverse flatness tolerance is the maximum deviation from a reference base across any cross-section flat surface.

FIG. 2 TRANSVERSE FLATNESS TOLERANCES

TABLE 1
PRODUCT ANALYSIS TOLERANCES

NOTE—This table specifies tolerances over the maximum limits or under the minimum limits of the chemical requirements of the applicable material specification (see 1.1); it does not apply to heat analysis.

Element	Upper Limit or Maximum of Specified Range, %	Tolerances over the Maximum (Upper Limit) or Under the Minimum (Lower Limit)
Carbon	to 0.010, incl	0.002
	over 0.010 to 0.030, incl	0.005
	over 0.030 to 0.20, incl	0.01
	over 0.20 to 0.60, incl	0.02
	over 0.60 to 1.20, incl	0.03
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
	over 3.00 to 6.00, incl	0.05
	over 6.00 to 10.00, incl	0.06
	over 10.00 to 15.00, incl	0.10
	over 15.00 to 20.00, incl	0.15
Phosphorus	to 0.040, incl	0.005
	over 0.040 to 0.20, incl	0.010
Sulfur	to 0.040, incl	0.005
	over 0.040 to 0.20, incl	0.010
	over 0.20 to 0.50, incl	0.020
Silicon	to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.10
	over 3.00 to 6.00, incl	0.15
Chromium	over 4.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
	over 15.00 to 20.00, incl	0.20
	over 20.00 to 30.00, incl	0.25
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
	over 20.00 to 30.00, incl	0.20
	over 30.00 to 40.00, incl	0.25
	over 40.00	0.30
Molybdenum	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
	over 2.00 to 7.00, incl	0.10
	over 7.00 to 15.00, incl	0.15
	over 15.00 to 30.00, incl	0.20
Titanium	to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.07
	over 3.00	0.10
Cobalt	over 0.05 to 0.50, incl	0.01
	over 0.50 to 2.00, incl	0.02
	over 2.00 to 5.00, incl	0.05
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
	over 15.00 to 22.00, incl	0.20
	over 22.00 to 30.00, incl	0.25
Columbium + tantalum	to 1.50, incl	0.05
	over 1.50 to 5.00, incl	0.10
	over 5.00	0.15
Tantalum	to 0.10, incl	0.02
Copper	to 0.50, incl	0.03
	over 0.50 to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.10
	over 3.00 to 5.00, incl	0.15
	over 5.00 to 10.00, incl	0.20
Aluminum	to 0.15, incl	−0.005 +0.01
	over 0.15 to 0.50, incl	0.05
	over 0.50 to 2.00, incl	0.10
	over 2.00 to 5.00, incl	0.20
	over 5.00 to 10.00, incl	0.35
Nitrogen	to 0.02, incl	0.005
	over 0.02 to 0.19, incl	0.01
	over 0.19 to 0.25, incl	0.02
	over 0.25 to 0.35, incl	0.03
	over 0.35 to 0.45, incl	0.04
	over 0.45	0.05
Tungsten	to 1.00, incl	0.03
	over 1.00 to 2.00, incl	0.05
	over 2.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
Vanadium	to 0.50, incl	0.03
	over 0.50 to 1.50, incl	0.05
Selenium	all	0.03

TABLE 2
PERMISSIBLE VARIATIONS IN SIZE OF HOT-FINISHED ROUND, TURNED,[D] AND SQUARE BARS

Specified Size, in. [mm]	Permissible Variations from Specified Size, in. [mm]		Out-of-Round[A] or Out-of-Square,[B] in. [mm]
	Over	Under	
5/16 to 7/16 [8.00 to 11.00], incl[C]	0.006 [0.15]	0.006 [0.15]	0.009 [0.23]
Over 7/16 to 5/8 [11.00 to 15.50], incl[C]	0.007 [0.18]	0.007 [0.18]	0.010 [0.26]
Over 5/8 to 7/8 [15.50 to 22.00], incl	0.008 [0.20]	0.008 [0.20]	0.012 [0.30]
Over 7/8 to 1 [22.00 to 25.00], incl	0.009 [0.23]	0.009 [0.23]	0.013 [0.34]
Over 1 to 1 1/8 [25.00 to 28.00], incl	0.010 [0.25]	0.010 [0.25]	0.015 [0.38]
Over 1 1/8 to 1 1/4 [28.00 to 31.50], incl	0.011 [0.28]	0.011 [0.28]	0.016 [0.42]
Over 1 1/4 to 1 3/8 [31.50 to 34.50], incl	0.012 [0.30]	0.012 [0.30]	0.018 [0.46]
Over 1 3/8 to 1 1/2 [34.50 to 38.00], incl	0.014 [0.35]	0.014 [0.35]	0.021 [0.53]
Over 1 1/2 to 2 [38.00 to 50.00], incl	1/64 [0.40]	1/64 [0.40]	0.023 [0.60]
Over 2 to 2 1/2 [50.00 to 63.00], incl	1/32 [0.80]	0	0.023 [0.60]
Over 2 1/2 to 3 1/2 [63.00 to 90.00], incl	3/64 [1.20]	0	0.035 [0.90]
Over 3 1/2 to 4 1/2 [90.00 to 115.00], incl	1/16 [1.60]	0	0.046 [1.20]
Over 4 1/2 to 5 1/2 [115.00 to 140.00], incl	5/64 [2.00]	0	0.058 [1.50]
Over 5 1/2 to 6 1/2 [140.00 to 165.00], incl	1/8 [3.00]	0	0.070 [1.80]
Over 6 1/2 to 8 [165.00 to 200.00], incl	5/32 [4.00]	0	0.085 [2.20]
Over 8 to 12 [200.00 to 300.00], incl[D]	3/16 [4.80]	0	3/32 [2.40]
Over 12 to 15 [300.00 to 400.00], incl[D]	7/32 [5.50]	0	7/64 [2.80]
Over 15 to 25 [400.00 to 625.00], incl[D]	1/4 [6.50]	0	1/8 [3.20]

[A] Out-of-round is the difference between the maximum and minimum diameters of the bar measured at the same cross section.
[B] Out-of-square section is the difference in the two dimensions at the same cross section of a square bar, each dimension being the distance between opposite faces.
[C] Size tolerances have not been evolved for round sections in the size range of 5/16 in. [8.00 mm] to approximately 5/8 [15.5 mm] in diameter which are produced on rod mills in coils.
[D] Turned bars are generally available from 2 to 25 in. [50 to 625 mm] in diameter, over 8 in. [200 mm] only turned bars are available.

TABLE 3
PERMISSIBLE VARIATIONS IN SIZE OF HOT-FINISHED HEXAGONAL AND OCTAGONAL BAR

Specified Sizes Measured Between Opposite Sides, in. [mm]	Permissible Variations from Specified Size, in. [mm]		Maximum Difference in 3 Measurements for Hexagons Only, in. [mm]
	Over	Under	
1/4 to 1/2 [6.50 to 13.00], incl	0.007 [0.18]	0.007 [0.18]	0.011 [0.28]
Over 1/2 to 1 [13.00 to 25.00], incl	0.010 [0.25]	0.010 [0.25]	0.015 [0.38]
Over 1 to 1 1/2 [25.00 to 38.00], incl	0.021 [0.53]	0.021 [0.53]	0.025 [0.64]
Over 1 1/2 to 2 [38.00 to 50.00], incl	1/32 [0.80]	1/32 [0.80]	1/32 [0.80]
Over 2 to 2 1/2 [50.00 to 63.00], incl	3/64 [1.20]	3/64 [1.20]	3/64 [1.20]
Over 2 1/2 to 3 1/2 [63.00 to 90.00], incl	1/16 [1.60]	1/16 [1.60]	1/16 [1.60]

TABLE 4
PERMISSIBLE VARIATIONS IN THICKNESS AND WIDTH FOR HOT-FINISHED FLAT BARS ROLLED AS BARS

Specified Width, in. [mm]	Permissible Variations in Thickness for Thicknesses Given, in. [mm]												Permissible Variations in Width, in. [mm]	
	1/8 to 1/2 [3.2 to 13], incl		Over 1/2 to 1 [13 to 25], incl		Over 1 to 2 [25 to 50], incl		Over 2 to 4 [50 to 100], incl		Over 4 to 6 [100 to 150], incl		Over 6 to 8 [150 to 200], incl			
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
To 1 [25.00], incl	0.008 [0.20]	0.008 [0.20]	0.010 [0.25]	0.010 [0.25]	...	...	...	...	...	...	...	...	0.015 [0.40]	0.015 [0.40]
Over 1 to 2 [25.00 to 50.00], incl	0.012 [0.30]	0.012 [0.30]	0.015 [0.40]	0.015 [0.40]	0.031 [0.80]	0.031 [0.80]	...	...	...	...	...	...	0.031 [0.80]	0.031 [0.80]
Over 2 to 4 [50.00 to 100.00], incl	0.015 [0.40]	0.015 [0.40]	0.020 [0.50]	0.020 [0.50]	0.031 [0.80]	0.031 [0.80]	0.062 [1.60]	0.031 [0.80]	...	...	...	...	0.062 [1.60]	0.031 [0.80]
Over 4 to 6 [100.00 to 150.00], incl	0.015 [0.40]	0.015 [0.40]	0.020 [0.50]	0.020 [0.50]	0.031 [0.80]	0.031 [0.80]	0.062 [1.60]	0.031 [0.80]	0.093 [2.40]	0.062 [1.60]	...	...	0.093 [2.40]	0.062 [1.60]
Over 6 to 8 [150.00 to 200.00], incl	0.016 [0.40]	0.016 [0.40]	0.025 [0.65]	0.025 [0.65]	0.031 [0.80]	0.031 [0.80]	0.062 [1.60]	0.031 [0.80]	0.093 [2.40]	0.062 [1.60]	0.125 [3.20]	0.156 [4.00]	0.125 [3.20]	0.156 [4.00]
Over 8 to 10 [200.00 to 250.00], incl	0.020 [0.50]	0.020 [0.50]	0.031 [0.80]	0.031 [0.80]	0.031 [0.80]	0.031 [0.80]	0.062 [1.60]	0.031 [0.80]	0.093 [2.40]	0.062 [1.60]	0.125 [3.20]	0.156 [4.00]	0.156 [4.00]	0.187 [4.80]

TABLE 5
PERMISSIBLE VARIATIONS IN DIMENSIONS FOR FLAT BARS CUT FROM STRIP OR PLATE

Order Thickness	Permissible Variation in Thickness, in. [mm]		Permissible Variation[A] in Width				Permissible Variation in Length[B]	
			Widths to 4 [100]		Widths Over 4 [100]			
	Over	Under	Over	Under	Over	Under	Over	Under
Over 0.114 to 0.130 [2.90 to 3.30], incl	0.010	0.010	0.094	0.031	0.094	0.094	0.188	0
	[0.25]	[0.25]	[2.40]	[0.80]	[2.40]	[2.40]	[4.80]	0
Over 0.130 to 0.145 [3.30 to 3.70], incl	0.012	0.012	0.094	0.031	0.094	0.094	0.188	0
	[0.30]	[0.30]	[2.40]	[0.80]	[2.40]	[2.40]	[4.80]	0
Over 0.145 to less than 3/16, [3.70 to 4.80]	0.014	0.014	0.094	0.031	0.094	0.094	0.188	0
	[0.35]	[0.35]	[2.40]	[0.80]	[2.40]	[2.40]	[4.80]	0
3/16 to 3/8 [4.80 to 9.00], excl	0.050	0.010	0.094	0.031	0.094	0.094	0.188	0
	[1.25]	[0.25]	[2.40]	[0.80]	[2.40]	[2.40]	[4.80]	0
3/8 to 3/4 [9.00 to 19.00], excl	0.060	0.010	0.094	0.031	0.094	0.094	0.188	0
	[1.50]	[0.25]	[2.40]	[0.80]	[2.40]	[2.40]	[4.80]	0
3/4 to 1 [19.00 to 25.00], excl	0.065	0.010	0.094	0.031	0.094	0.094	0.188	0
	[1.65]	[0.25]	[2.40]	[0.80]	[2.40]	[2.40]	[4.80]	0
1 to 2 [25.00 to 50.00], excl	0.075	0.010	0.094	0.031	0.094	0.094	0.188	0
	[1.90]	[0.25]	[2.40]	[0.80]	[2.40]	[2.40]	[4.80]	0
2 to 3 [50.00 to 75.00], excl	0.150	0.010	0.125	0.062	0.125	0.125	0.250	0
	[3.80]	[0.25]	[3.00]	[1.60]	[3.00]	[3.00]	[6.50]	0
3 to 4 [75.00 to 100.00], excl	0.210	0.010	0.125	0.062	0.125	0.125	0.250	0
	[5.30]	[0.25]	[3.00]	[1.60]	[3.00]	[3.00]	[6.50]	0
4 to 6 [100.00 to 150.00], excl	0.300	0.010	0.125	0.062	0.125	0.125	0.250	0
	[7.60]	[0.25]	[3.00]	[1.60]	[3.00]	[3.00]	[6.50]	0
6 to 8 [150.00 to 200.00], excl	0.420	0.010	0.125	0.062	0.125	0.125	0.250	0
	[10.65]	[0.25]	[3.00]	[1.60]	[3.00]	[3.00]	[6.50]	0
8 to 10 [200.00 to 250.00], excl	0.540	0.010	0.125	0.062	0.125	0.125	0.250	0
	[13.70]	[0.25]	[3.00]	[1.60]	[3.00]	[3.00]	[6.50]	0

[A] By agreement between purchaser and seller, tolerances can be shifted as desired to any combination of plus-minus tolerance between all minus and all plus.
[B] Not applicable when bars are ordered random length.

TABLE 6
PERMISSIBLE VARIATIONS IN SIZE OF COLD-FINISHED ROUND BARS

Specified Size, in. [mm]	Permissible Variations from Specified Size, in. [mm][A,B]	
	Over	Under
1/16 to 5/16 [1.50 to 8.00], excl	0.001 [0.03]	0.001 [0.03]
5/16 to 1/2 [8.00 to 13.00], excl	0.0015 [0.04]	0.0015 [0.04]
1/2 to 1 [13.00 to 25.00], excl	0.002 [0.05]	0.002 [0.05]
1 to 1 1/2 [25.00 to 38.00], excl	0.0025 [0.06]	0.0025 [0.06]
1 1/2 to 4 [38.00 to 100.00], incl[C]	0.003 [0.08]	0.003 [0.08]

[A] Unless otherwise specified, size tolerances are over and under as shown in the above table. When required, however, they may be specified all over and nothing under, or all under and nothing over, or any combination of over and under, if the total spread in size tolerance for a specified size is not less than the total spread shown in the table.

[B] When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.

[C] Cold-finished bars over 4 in. [100 mm] in diameter are produced; size tolerances for such bars are not included herein.

TABLE 7
PERMISSIBLE VARIATIONS IN SIZE OF COLD FINISHED HEXAGONAL, OCTAGONAL, AND SQUARE BARS

Specified Size,[A] in. [mm]	Permissible Variations from Specified Size, in. [mm][B]	
	Over	Under
1/8 to 5/16 [3.00 to 8.00], excl	0	0.002 [0.05]
5/16 to 1/2 [8.00 to 13.00], excl	0	0.003 [0.08]
1/2 to 1 [13.00 to 25.00], incl	0	0.004 [0.10]
Over 1 to 2 [25.00 to 50.00], incl	0	0.006 [0.15]
Over 2 to 3 [50.00 to 75.00], incl	0	0.008 [0.20]
Over 3 [75.00]	0	0.010 [0.25]

[A] Distance across flats.

[B] When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.

TABLE 8
PERMISSIBLE VARIATIONS IN WIDTH AND THICKNESS OF COLD-FINISHED FLAT BARS

Width, in. [mm]	Permissible Variations in Width, Over and Under, in. [mm][A]	
	For Thicknesses 1/4 in. [6.5] and Under	For Thicknesses Over 1/4 in. [6.5]
1/16 to 3/8 [1.50 to 9.50], incl	0.005 [0.12]	0.005 [0.12]
Over 3/8 to 1 [9.50 to 25.00], incl	0.004 [0.10]	0.004 [0.10]
Over 1 to 2 [25.00 to 50.00], incl	0.006 [0.15]	0.004 [0.10]
Over 2 to 3 [50.00 to 75.00], incl	0.008 [0.20]	0.004 [0.10]
Over 3 to 4 1/2 [75.00 to 115.00], incl	0.010 [0.25]	0.005 [0.13]

Thickness, in. [mm]	Permissible Variations in Thickness, Over and Under, in. [mm][A]
Up to .029 [0.70], incl	0.001 [0.03]
Over .029 to .035 [0.70 to 1.00], incl	0.0015 [0.04]
Over .035 to 1 [1.00 to 25.00], incl	0.002 [0.05]
Over 1 to 2 [25.00 to 50.00], incl	0.003 [0.08]
Over 2 to 3 [50.00 to 75.00], incl	0.004 [0.10]
Over 3 to 4 1/2 [75.00 to 115.00], incl[B]	0.005 [0.13]

[A] When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.

[B] Cold-finished flat bars over 4 1/2 in. [115 mm] wide or thick are produced; width and thickness tolerances for such bars are not included herein.

TABLE 9
PERMISSIBLE VARIATIONS IN LENGTH OF HOT-FINISHED OR COLD-FINISHED BARS

NOTE — These tolerances are not applicable when bars are ordered random length.

Specified Size of Rounds, Squares, Hexagons, Octagons, and Widths of Flats,[B] in. [mm]	Permissible Variations in Length, in. [mm][A]			
	For Lengths up to 12 ft[C] [4 m], incl		For Lengths Over 12 to 25 ft [4 to 8 m], incl	
	Over	Under	Over	Under
Up to .500 [13.00], incl	1/16 [1.5]	0	1/8 [3.0]	0
Over .500 to 2 [13.00 to 50.00], incl	1/2 [13]	0	3/4 [19.0]	0
Over 2 to 4 [50.00 to 100.00], incl	3/4 [19]	0	1 [25.00]	0
Over 4 to 6 [100.00 to 150.00], incl	1 [25]	0	1 1/4 [31.50]	0
Over 6 to 9 [150.00 to 225.00], incl	1 1/4 [31.5]	0	1 1/2 [38.00]	0
Over 9 to 12 [225.00 to 300.00], incl	1 1/2 [38]	0	2 [50.00]	0

[A] Random Lengths — When ordered as random lengths, permissible variation is 2 ft [0.6 m] over and under the specified length. When ordered as random lengths subject to a minimum length requirement, permissible variation is 2 ft [0.6 m] over and nothing under the specified length.

[B] The maximum width of bar flats is 10 in. [250 mm].

[C] For lengths under 3 ft [1 m] and sizes up to 1/2 in. [13.00 mm] incl., the permissible variation in length is 1/32 in. [0.80 mm] over and nothing under.

TABLE 10
PERMISSIBLE VARIATIONS IN LENGTH OF HOT-FINISHED OR COLD-FINISHED BARS MACHINE CUT AFTER MACHINE STRAIGHTENING

NOTE — These tolerances are not applicable when bars are ordered random length.

Specified Size of Rounds, Squares, Hexagons, Octagons, and Width of Flats,[A] in. [mm]	Permissible Variations in Length, in. [mm]			
	For Lengths up to 12 ft [4 m], incl		For Lengths Over 12 to 25 ft [4 to 8 m], incl	
	Over	Under	Over	Under
To 3 [75], incl	1/8 [3.0]	0	3/16 [4.8]	0
Over 3 to 6 [75 to 150], incl	3/16 [4.8]	0	1/4 [6.5]	0
Over 6 to 9 [150 to 225], incl	1/4 [6.5]	0	5/16 [8.0]	0
Over 9 to 12 [225 to 300], incl	1/2 [13.0]	0	1/2 [13.0]	0

[A] The maximum width of bar flats is 10 in. [250 mm].

TABLE 11
PERMISSIBLE VARIATIONS IN STRAIGHTNESS OF MACHINE STRAIGHTENED HOT-FINISHED OR COLD-FINISHED BARS[A]

Measurement is taken on the concave side of the bar with a straightedge. Unless otherwise specified, hot-finished or cold-finished bars for machining purposes are furnished machine straightened to the following tolerances:

Hot finished:

1/8 in. [3.00 mm] in any 5 ft [1.50 m]; but may not exceed
1/8 in. [3.00 mm] × (length in ft/5) [m/1.50]

Cold finished:

1/16 in. [1.5 mm] in any 5 ft [1.5 m]; but may not exceed
1/16 in. [1.5 mm] × (length in ft/5) [m/1.50]

[A] Straightness tolerances have not been established for sizes less than 1/2 in. [6.50 m].

TABLE 12
PERMISSIBLE VARIATIONS FOR HOT-FINISHED ANGLES

NOTE — For unequal leg angles, the longer leg determines the tolerance for the length of each leg.

Weight:[A]

For angles of 6 lb/ft [9.0 kg/m] or less, the weight tolerances shall not exceed ±7½%. For angles over 6 lb/ft [9 kg/m], the weight tolerance shall not exceed ±4½%.

Length of Legs:

For angles having legs or flanges up to 6 in. [150 mm], incl, the length tolerance shall not exceed ±1/8 in. [3.00 mm]. For angles having legs or flanges over 6 in., the length tolerance shall not exceed +3/16 in. [5.00 mm] and −1/8 in.

Squareness of Legs:

The tolerance for the right angle between the legs is ±2°.

[A] For equal leg angles, the theoretical weight per foot is:

$$\text{Weight/foot} = (24\ W \times t - 12t^2)\ (0.2871\ \text{lb/ft})$$

where W is the specified length of the leg, and t is the specified thickness, both in inches.

For unequal leg angles, the theoretical weight per foot is:

$$\text{Weight/foot} = [12\ W1 \times t + 12\ W2 \times t - 12t^2]\ (0.2871\ \text{lb/ft})$$

where $W1$ and $W2$ are the specified leg lengths, and t is the specified leg thickness, all in inches.

TABLE 13
PERMISSIBLE VARIATIONS IN SIZE OF HOT-FINISHED CHANNELS

Specified Size of Channel, in. [mm]	Size Tolerances, Over and Under, in. [mm]				
	Depth of Section[A]	Width of Flanges	Thickness of Web for Thickness Given		Out-of-Square[B] of Either Flange, in./in. [mm/mm] of Flange Width
			To 3/16 incl [5.00 mm]	Over 3/16 [5.00 mm]	
To 1½ [38.00], incl	3/64 [1.20]	3/64 [1.20]	0.015 [0.41]	0.023 [0.60]	3/64 [1.20]
Over 1½ to 3 [38.00 to 75.00], excl	3/32 [2.40]	3/32 [2.40]	0.023 [0.60]	0.030 [0.80]	3/64 [1.20]

[A] Channel depth is measured at back of web.
[B] For channels 5/8 in. [15.50 mm] and under in depth, the out-of-square tolerance is 5/64 in./in. [2.00 mm/mm] of depth. Out-of-squareness is determined by placing a square against the bottom surface of the web and measuring the amount of toe-in or toe-out of either flange. Measurements for depth of section and width of flanges are over-all.

TABLE 14
PERMISSIBLE VARIATIONS IN SIZE OF HOT-FINISHED TEES

Specified Size of Tee, in. [mm][A]	Width or Depth, in.		Thickness of Flange, in. [mm]		Thickness of Stem, in. [mm]		Stem Out-of-Square[C] in. [mm]
	Over	Under	Over	Under	Over	Under	
To 1½ [38.00], incl	5/64 [2.00]	5/64 [2.00]	0.015 [0.38]	0.015 [0.38]	0.008 [0.20]	0.030 [0.75]	3/64 [1.20]
Over 1½ to 2 [38.00 to 50.00], incl	3/32 [2.40]	3/32 [2.40]	0.018 [0.46]	0.018 [0.46]	0.015 [0.38]	0.030 [0.75]	3/32 [2.40]
Over 2 to 3 [50.00 to 75.00], excl	9/64 [3.60]	9/64 [3.60]	0.023 [0.60]	0.023 [0.60]	0.023 [0.60]	0.030 [0.75]	9/64 [3.60]

[A] The longer member of an unequal tee determines the size for tolerances.
[B] Measurements for both width and depth are over-all.
[C] Stem out-of-square is the variation from its true position of the center line of stem measured at the point.

TABLE 15
PERMISSIBLE VARIATIONS IN SIZE OF HOT-EXTRUDED SHAPES

Specified Size, in. [mm]	Section Tolerances, in. [mm]	
	Over	Under
Dimensions under 1 [25]	0.020 [0.50]	0.020 [0.50]
Dimensions 1 to 3 [25 to 75], excl	0.031 [0.80]	0.031 [0.80]
Dimensions 3 to 4 [75 to 100], incl.	0.046 [1.20]	0.046 [1.20]
Over 4 [100]	0.062 [1.60]	0.062 [1.60]

TABLE 16
ANGULARITY TOLERANCE FOR EXTRUDED SHAPES

Plus and minus	max 2°

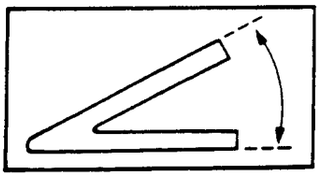


TABLE 17
LENGTH TOLERANCES FOR EXTRUDED SHAPE LENGTH[A,B]

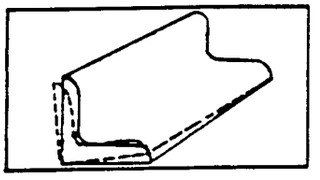
	For Lengths up to 12 ft [4 m], incl.		For Lengths over 12 ft [4 m]	
Specified Size	Over	Under	Over	Under
Up to 3 in. [75 mm], excl	3/16 in. [4.8 mm]	0	1/4 in. [6.5 mm]	0

[A] Multiple Lengths — Unless otherwise specified, 1/4 in. [6.5 mm] is added to the total length of each piece for each multiple contained.

[B] Random Lengths — When ordered as random lengths, permissible variation is 2 ft [0.6 m] over and under the specified length. When ordered as random lengths subject to a minimum length requirement, permissible variation is 2 ft [0.6 m] over and nothing under the specified length.

TABLE 18
TWIST TOLERANCES

NOTE — The amount of spiraling in an extruded shape is called twist. It can be measured by the height of the high corner from a flat reference base (established rise).



Using the following calculation, the twist tolerance must not exceed what is shown in the table.

$$\text{Rise in 5 ft.} = \frac{\text{established rise} \times \text{number of ft in length}}{5}$$

Section Width	Rise in 5 ft
1/2 in. [13 mm] to 1 1/2 in. [39 mm]	0.125 in. [3.00 mm]
Over 1 1/2 in. [39 mm] to 4 in. [100 mm]	0.188 in. [4.80 mm]
Over 4 in. [100 mm]	0.250 in. [6.50 mm]

APPENDICES

(Nonmandatory Information)

X1. RATIONALE REGARDING DEFINITION OF LOT FOR MECHANICAL PROPERTIES AND CORROSION TESTING

X1.1 It is generally recognized that material described as a lot must be "produced under the same processing conditions," which means the same manufacturing order number, same size, same heat, same heat-treating procedure, and same subsequent processing. Under those conditions, single samples can be selected to be representitive of the total lot, with at least one sample for each 20 000 pounds of material.

X1.2 Following the principle described in X1.1 generally requires that the producer control each of several furnace loads constituting the same lot so that:

X1.2.1 Set point temperature and process tolerance match,

X1.2.2 Time at temperature for all thermal treatment shall match within 10%,

X1.2.3 All furnaces used be similar in size and meet the uniformity requirements of a documented furnace quality assurance program and,

X1.2.4 The quench systems are the same with respect to volume, type of quenchant, and circulation rate.

X1.2.5 Further, it would be expected that grouped loads be handles within a relatively short time period, and that hardness testing be performed on at least one sample per charge.

X1.3 The old definition of a lot for mechanical testing based on simply the words "same size, heat, and heat treatment charge in a batch furnace" assumes that heat treating is the only process affecting properties. This kind of definition ignores the effects of other processing, prior to and subsequent to heat treating. Moreover, it assumes that each heat-treated batch will be uniform and unique rather than reproducible. In reality, heat treating is a process which can be controlled easily throughout a batch and from batch to batch, with the net result that multiple batches can be considered part of a single lot if equipment and processing parameters meet the mandates of X1.1 and X1.2.

X1.4 The sampling specified for mechanical properties is not a statistical sampling plan. Therefore, it provides only typical data. Assurance of uniformity within the lot can be obtained only by the producer adequately controlling the processing parameters.

X2. BAR CODING

X2.1 Bar coding to identify steel is not specifically addressed in Committee A-1 specifications. Committee A-1 endorses the AIAG bar code standard for primary metals for steel products and proposes that this bar coding standard be considered as a possible auxiliary method of identification.

SPECIFICATION FOR STEEL CASTINGS SUITABLE FOR PRESSURE SERVICE

SA-487/SA-487M

(Identical with ASTM Specification A 487/A 487M-93.) 98

1. Scope

1.1 This specification covers low-alloy steels and martensitic stainless steels in the normalized and tempered, or quenched and tempered, condition suitable for pressure-containing parts. The weldability of the classes in this specification varies from readily weldable to weldable only with adequate precautions, and the weldability of each class should be considered prior to assembly by fusion welding.

1.2 Selection will depend on design, mechanical, and service conditions. Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtained.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 487 and SI units for material ordered to Specification A 487M.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

E 165 Practice for Liquid Penetrant Method

E 709 Practice for Magnetic Particle Examination

2.2 *American Society of Mechanical Engineers:*

ASME Boiler and Pressure Vessel Code, Section IX

2.3 *Manufacturers Standardization Society of the Valve and Fittings Industry Standards:*

SP-55 Quality Standard for Steel Castings — Visual Method

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the applicable requirements of Specification A 703/A 703M, including the supplementary requirements that are indicated on the purchase order. Failure to comply with the general requirements of Specification A 703/A 703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 703/A 703M, this specification shall prevail. 98

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),

4.1.2 ASTM designation and year of issue,

4.1.3 Grade and class of steel,

4.1.4 Options in the specification, and

4.1.5 The supplementary requirements desired including the standard of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment indicated in Table 1. Preliminary heat treatment prior to final heat treatment as well as multiple tempering is permitted.

5.2 Heat treatment shall be performed after the castings have been allowed to cool below the transformation range.

5.3 The furnace temperature for heat treating shall be effectively controlled by use of recording-type pyrometers.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2. Product analysis tolerance shall conform to the product analysis tolerance shown in Specification A 703/A 703M. Product analysis tolerances for stainless grades are not presently applicable pending development of these limits.

7. Tensile Requirements

7.1 Tensile properties of steel used for the castings shall conform to the requirements prescribed in Table 3.

8. Quality

8.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Method SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities. When methods involving high temperatures are used in the removal and repair of discontinuities, the casting shall be preheated to at least the minimum temperature in Table 4.

8.2 The castings shall not be peened, plugged, or impregnated to stop leaks.

9. Repair By Welding

9.1 For castings, other than those intended for use under ASME Boiler and Pressure Vessel Code, repairs shall be made using procedures and welders qualified under Practice A 488/A 488M.

9.2 On castings intended for use under the ASME Boiler and Pressure Vessel Code, repairs shall be made by procedures and welders qualified under Section IX of that code.

9.3 After repair welding, all castings shall be postweld heat treated in accordance with Table 4 or reheat treated in accordance with Table 1.

9.4 Weld repairs shall be inspected using the same quality standards as are used to inspect the castings. Re-examination of the weld repair by radiography when Supplementary Requirement S5 has been specified will not be necessary when an applicable surface inspection method was used to locate the discontinuity except for the following:

9.4.1 Weld repairs on castings which have leaked on hydrostatic test.

9.4.2 Weld repairs on castings in which the depth of any cavity prepared for repair welding is more than 20% of the wall thickness or 1 in. [25 mm], whichever is smaller.

9.4.3 Weld repairs on castings in which any cavity prepared for welding is greater than approximately 10 $in.^2$ [65 cm^2].

10. Product Marking

10.1 Castings shall be marked for material identification with the grade and class symbols (1-A, 4-C, CA15-A).

98

TABLE 1
HEAT TREAT REQUIREMENT

Grade	Class	Austenitizing Temperature, min, °F [°C]	Media[A]	Quenching Cool Below °F[°C]	Tempering Temperature, °F [°C][B]
1	A	1600 [870]	A	450 [230]	1100 [595]
1	B	1600 [870]	L	500 [260]	1100 [595]
1	C	1600 [870]	A or L	500 [260]	1150 [620]
2	A	1600 [870]	A	450 [230]	1100 [595]
2	B	1600 [870]	L	500 [260]	1100 [595]
2	C	1600 [870]	A or L	500 [260]	1150 [620]
4	A	1600 [870]	A or L	500 [260]	1100 [595]
4	B	1600 [870]	L	500 [260]	1100 [595]
4	C	1600 [870]	A or L	500 [260]	1150 [620]
4	D	1600 [870]	L	500 [260]	1150 [620]
4	E	1600 [870]	L	500 [260]	1100 [595]
6	A	1550 [845]	A	500 [260]	1100 [595]
6	B	1550 [845]	L	500 [260]	1100 [595]
7	A	1650 [900]	L	600 [315]	1100 [595]
8	A	1750 [955]	A	500 [260]	1250 [675]
8	B	1750 [955]	L	500 [260]	1250 [675]
8	C	1750 [955]	L	500 [260]	1250 [675]
9	A	1600 [870]	A or L	500 [260]	1100 [595]
9	B	1600 [870]	L	500 [260]	1100 [595]
9	C	1600 [870]	A or L	500 [260]	1150 [620]
9	D	1600 [870]	L	500 [260]	1150 [620]
9	E	1600 [870]	L	500 [260]	1100 [595]
10	A	1550 [845]	A	500 [260]	1100 [595]
10	B	1550 [845]	L	500 [260]	1100 [595]
11	A	1650 [900]	A	600 [315]	1100 [595]
11	B	1650 [900]	L	600 [315]	1100 [595]
12	A	1750 [955]	A	600 [315]	1100 [595]
12	B	1750 [955]	L	400 [205]	1100 [595]
13	A	1550 [845]	A	500 [260]	1100 [595]
13	B	1550 [845]	L	500 [260]	1100 [595]
14	A	1550 [845]	L	500 [260]	1100 [595]
16	A	1600 [870][C]	A	600 [315]	1100 [595]
CA15	A	1750 [955]	A or L	400 [205]	900 [480]
CA15	B	1750 [955]	A or L	400 [205]	1100 [595]
CA15	C	1750 [955]	A or L	400 [205]	1150 [620][D,E]
CA15	D	1750 [955]	A or L	400 [205]	1150 [260][D,E]
CA15M	A	1750 [955]	A or L	400 [205]	1100 [595]
CA6NM	A	1850 [1010]	A or L	200 [95]	1050–1150 [565–620]
CA6NM	B	1850 [1010]	A or L	200 [95]	1225–1275 [665–690][E,F] 1050–1150 [565–620][G]

[A] A = air, L = Liquid.
[B] Minimum temperature unless range is specified.
[C] Double austenitize.
[D] Double temper with the final temper at a lower temperature than the intermediate temper.
[E] Air cool to below 200°F [95°C] after first temper.
[F] Intermediate.
[G] Final.

TABLE 2
CHEMICAL REQUIREMENTS (MAXIMUM PERCENT UNLESS RANGE IS GIVEN)

Grade	1.	2.	4.	6.	7.	8.	9.	10.	11.	12.
Class Type	ABC Vanadium	ABC Manganese-Molybdenum	ABCDE Nickel-Chromium-Molybdenum	AB Manganese Nickel-Chromium-Molybdenum	A Nickel-Chromium-Molybdenum-Vanadium[A]	ABC Chromium-Molybdenum	ABCDE Chromium-Molybdenum	AB Nickel-Chromium-Molybdenum	AB Nickel-Chromium-Molybdenum	AB Nickel-Chromium-Molybdenum
Carbon	0.30	0.30	0.30	0.05–0.38	0.05–0.20	0.05–0.20	0.05–0.33	0.30	0.05–0.20	0.05–0.20
Manganese	1.00	1.00–1.40	1.00	1.30–1.70	0.60–1.00	0.50–0.90	0.60–1.00	0.60 to 1.00	0.50–0.80	0.40–0.70
Phosphorus	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sulfur	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Silicon	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.60	0.60
Nickel	. . .	. . .	0.40–0.80	0.40–0.80	0.70–1.00	. . .	. . .	1.40–2.00	0.70–1.10	0.60–1.00
Chromium	. . .	. . .	0.40–0.80	0.40–0.80	0.04–0.80	2.00–2.75	0.75–1.10	0.55–0.90	0.50–0.80	0.50–0.90
Molybdenum	. . .	0.10–0.30	0.15–0.30	0.30–0.40	0.40–0.60	0.90–1.10	0.15–0.30	0.20–0.40	0.45–0.65	0.90–1.20
Vanadium	0.04–0.12	. . .	. . .	. . .	0.03–0.10	. . .	. . .	. . .	. . .	. . .
Boron	. . .	. . .	. . .	. . .	0.002–0.006	. . .	. . .	. . .	. . .	. . .
Copper	. . .	. . .	. . .	. . .	0.15–0.50	. . .	. . .	. . .	. . .	. . .
Residual Elements:										
Copper	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Nickel	0.50	0.50	. . .	. . .	. . .	. . .	0.50	. . .	. . .	. . .
Chromium	0.35	0.35	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Mo + W	0.25	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Tungsten	. . .	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Vanadium	. . .	0.03	0.03	0.03	. . .	0.03	0.03	0.03	0.03	0.03
Total content of residual elements	1.00	1.00	0.60	0.60	0.60	0.60	1.00	0.60	0.50	0.50

Grade	13.	14.	16.	CA15	CA15M	CA6NM
Class Type	AB Nickel-Molybdenum	A Nickel-Molybdenum	A Low Carbon Manganese-Nickel	ABCD Martensitic Chromium	A Martensitic Chromium	AB Martensitic Chromium Nickel
Carbon	0.30	0.55	0.12[B]	0.15	0.15	0.06
Manganese	0.80–1.10	0.80–1.10	2.10[B]	1.00	1.00	1.00
Phosphorus	0.04	0.04	0.02	0.040	0.040	0.04
Sulfur	0.045	0.045	0.02	0.040	0.040	0.03
Silicon	0.60	0.60	0.50	1.50	0.65	1.00
Nickel	1.40–1.75	1.40–1.75	1.00–1.40	1.00	1.0	3.5–4.5
Chromium	. . .	. . .	. . .	11.5–14.0	11.5–14.0	11.5–14.0
Molybdenum	0.20–0.30	0.20–0.30	. . .	0.50	0.15–1.0	0.4–1.0
Boron	. . .	. . .	. . .	. . .	. . .	. . .
Copper	. . .	. . .	. . .	. . .	. . .	. . .
Residual Elements:						
Copper	0.50	0.50	0.20	0.50	0.50	0.50
Nickel	. . .	. . .	. . .	. . .	. . .	. . .
Chromium	0.40	0.40	0.20	. . .	. . .	. . .
Molybdenum	. . .	. . .	0.10	. . .	. . .	. . .
Tungsten	0.10	0.10	0.10	0.10	0.10	0.10
Vanadium	0.03	0.03	0.02	0.05	0.05	0.05
Total content of residual elements	0.75	0.75	0.50	0.50	0.50	0.50

[A] Proprietary steel composition.
[B] For each reduction of 0.01% below the specified maximum carbon content, an increase of 0.04% manganese above the specified maximum will be permitted up to a maximum of 2.30%.

TABLE 3
REQUIRED MECHANICAL PROPERTIES

Previous Designation	Grade	Class	Tensile Strength,[A] min, ksi [MPa]	Yield Strength, min, ksi [MPa], at 0.2% Offset	Elongation, 2 in. [50 mm] or 4*d*, min, %	Reduction of Area, min, %	Hardness max, HRC	Max Thickness, in. [mm]
1N	1	A	85 [585]–110 [760]	55 [380]	22	40		
1Q	1	B	90 [620]–115 [795]	65 [450]	22	45		
	1	C	90 [620]	65 [450]	22	45	22 [235]	
2N	2	A	85 [585]–110 [750]	53 [365]	22	35		
2Q	2	B	90 [620]–115 [795]	65 [450]	22	40		
	2	C	90 [620]	65 [450]	22	40	22 [235]	
4N	4	A	90 [620]–115 [795]	60 [415]	18	40		
4Q	4	B	105 [725]–130 [895]	85 [585]	17	35		
	4	C	90 [620]	60 [415]	18	35	22 [235]	
	4	D	100 [690]	75 [515]	17	35	22 [235]	
4QA	4	E	115 [795]	95 [655]	15	35		
6N	6	A	115 [795]	80 [550]	18	30		
6Q	6	B	120 [825]	95 [655]	12	25		
7Q	7	A	115 [795]	100 [690]	15	30		2.5 [63.5]
8N	8	A	85 [585]–110 [760]	55 [380]	20	35		
8Q	8	B	105 [725]	85 [585]	17	30		
	8	C	100 [690]	75 [515]	17	35	22 [235]	
9N	9	A	90 [620]	60 [415]	18	35		
9Q	9	B	105 [725]	85 [585]	16	35		
	9	C	90 [620]	60 [415]	18	35	22 [235]	
	9	D	100 [690]	75 [515]	17	35	22 [235]	
	9	E	115 [795]	95 [655]	15	35		
10N	10	A	100 [690]	70 [485]	18	35		
10Q	10	B	125 [860]	100 [690]	15	35		
11N	11	A	70 [484]–95 [655]	40 [275]	20	35		
11Q	11	B	105 [725]–130 [895]	85 [585]	17	35		
12N	12	A	70 [485]– 95 [655]	40 [275]	20	35		
12Q	12	B	105 [725]–130 [895]	85 [585]	17	35		
13N	13	A	90 [620]–115 [795]	60 [415]	18	35		
13Q	13	B	105 [725]–130 [895]	85 [585]	17	35		
14Q	14	A	120 [825]–145 [1000]	95 [655]	14	30		
16N	16	A	70 [485]–95 [655]	40 [275]	22	35		
CA15A	CA15	A	140 [965]–170 [1170]	110 [760]–130 [895]	10	25		
CA15	CA15	B	90 [620]–115 [795]	65 [450]	18	30		
	CA15	C	90 [620]	60 [415]	18	35	22 [235]	
	CA15	D	100 [690]	75 [515]	17	35	22 [235]	
CA15M	CA15M	A	90 [620]–115 [795]	65 [450]	18	30		
CA6NM	CA6NM	A	110 [760]–135 [930]	80 [515]	15	35		
CA6NM	CA6NM	B	100 [690]	75 [520]	17	35	23 [255][B]	

[A] Minimum ksi, unless range is given.
[B] Test Methods and Definitions A 370, Table 3a does not apply to CA6NM. The conversion given is based on CA6NM test coupons. (For example, see ASTM STP 756.)

98

TABLE 4
MINIMUM PRE-HEAT AND POST WELD HEAT TREAT REQUIREMENTS

Grade	Class	Minimum Pre-Heat Temperature, °F [°C]	Post Weld Heat Treat, °F [°C]
1	A, B	200 [95]	1100 [595][A] minimum
1	C	200 [95]	1150 [620][A] minimum
2	A, B	200 [95]	1100 [595][A] minimum
2	C	200 [95]	1150 [620][A] minimum
4	A, B, E	200 [95]	1100 [595][A] minimum
4	C, D	200 [95]	1150 [620][A] minimum
6	A, B	300 [150]	1100 [595][A] minimum
7	A	300 [150]	1100 [595][A] minimum
8	A, B, C	300 [150]	1250 [675][A] minimum
9	A, B, E	300 [150]	1100 [595][A] minimum
9	C, D	300 [150]	1150 [620][A] minimum
10	A, B	300 [150]	1100 [595][A] minimum
11	A, B	300 [150]	1100 [595][A] minimum
12	A, B	300 [150]	1100 [595][A] minimum
13	A, B	400 [205]	1100 [595][A] minimum
14	A	400 [205]	1100 [595][A] minimum
16	A	50 [10]	1100 [595][A] minimum
CA15	A	400 [205]	1750 [955] air cool or liquid quench below 400°F [205°C] temper at 900°F [480°C] minimum
CA15	B	400 [205]	1100 [595][A] minimum
CA15	C, D	400 [205]	1150 [620][A] minimum
CA15M	A	400 [205]	1100 [595][A] minimum
CA6NM	A	50 [10]	Final temper between 1050 [565] and 1150 [620]
CA6NM	B	50 [10]	Intermediate PWHT between 1225 [665] and 1275 [690] Final temper PWHT 1050 [565] and 1150 [620][B]

[A] Post weld heat treat temperature must be at or below the final tempering temperature.

[B] The intermediate and final PWHT temperatures shall be the same as the intermediate and final tempering temperatures, respectively, as the original heat treatment of the castings. Cool to below 200°F (95°C) between the intermediate and final PWHT.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 703/A 703M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specification A 703/A 703M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S8. Charpy Impact Test

S8.1 In addition to the requirements listed in S8 of Specification A 703/A 703M, the following specific requirements apply to this specification:

S8.1.1 When S8 is specified for Grades 1B, 2B, 4B, 6B, 7A, 8B, 9B, or 10B, impact properties shall be determined by performing a Charpy V-notch impact test at −50°F [−46°C] with a specific minimum average value of 15 ft-lb [20 J] and a specified minimum single value of 10 ft-lb [14 J]. Other temperatures may be used upon agreement between the manufacturer and the purchaser, in which case S8.1.3 shall apply. Other higher specified minimum average and single values may be used upon agreement between the manufacturer and the purchaser.

S8.1.2 Impact requirements for grades other than 1B, 2B, 4B, 6B, 7A, 8B, 9B, and 10B shall be agreed upon between the manufacturer and the purchaser.

S8.1.3 When and impact test tmeperature other than −50°F [−46°C] is used for those grades listed in S8.1.1, the lowest test temperature at which the material meets the impact requirements shall be stamped with low stress stamps immediately ahead of the material symbol on the raised pad (for example, 25 10B for +25°F [−4°C] and 025 10B for −25°F [−32°C]).

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Practice E 709 or Practice E 165.

SPECIFICATION FOR CASTINGS, NICKEL AND NICKEL ALLOY

SA-494/SA-494M

(See Section II, Part B, SA-494/SA-494M)

SPECIFICATION FOR QUENCHED AND TEMPERED VACUUM-TREATED CARBON AND ALLOY STEEL FORGINGS FOR PRESSURE VESSELS

SA-508/SA-508M

(Identical with ASTM Specification A 508/A 508M-95.)

1. Scope

1.1 This specification covers quenched and tempered vacuum treated carbon and alloy steel forgings for pressure vessels such as those used in reactor systems. Specifically, it covers forgings for vessel closures, shell, flanges, tube sheets, rings, heads, and similar parts.

1.2 All grades are considered weldable under proper conditions. Welding technique is of fundamental importance, and it is presupposed that welding procedure and inspection will be in accordance with approved methods for the grade of material used.

1.3 The values stated in either inch-pounds units or SI (metric) units are to be regarded separately as standards. Within the text and the tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

NOTE 1 — Classes 1 and 1A are composed of different chemistries but have the same mechanical requirements.

NOTE 2 — Designations have been changed as follows:

Current	Formerly
Grade 1	Class 1
Grade 1A	Class 1A
Grade 2 Class 1	Class 2
Grade 2 Class 2	Class 2A
Grade 3 Class 1	Class 3
Grade 3 Class 2	Class 3A
Grade 4N Class 1	Class 4
Grade 4N Class 2	Class 4A
Grade 4N Class 3	Class 4B
Grade 5 Class 1	Class 5
Grade 5 Class 2	Class 5A
Grade 22 Class 3	Class 22B
Grade 3V	Class 3V

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 788 Specification for Steel Forgings, General Requirements

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

E 428 Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection

2.2 *American Society of Mechanical Engineers Standard:*

Boiler and Pressure Vessel Code – Section III, Articles NB-2300, NC-2300, ND-2300, NE-2300, NF-2300, NG-2300

3. Ordering Information

3.1 *Purchase Order* — In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order a detailed drawing that locates the areas of significant loading in the forging (when required), the method of selecting test locations (see 6.1.5 and 6.1.6), and purchase options (see 4.3.2, 6.2.1, and 10.1) and any supplementary requirements desired.

3.2 *Forging Drawing* — Each forging shall be manufactured in accordance with a purchaser-approved drawing showing the prequenched dimensions, the finished dimensions, the surfaces that will be subjected to significant loading, and the locations of mechanical test specimens.

3.3 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.4 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Melting Process:*

4.1.1 The steel shall be made by the basic electric-furnace process except when secondary ladle refining or the remelting process is employed, in which case the melting processes of Specification A 788 are permitted.

4.1.2 The molten steel shall be vacuum treated in accordance with the methods described in Specification A 788, prior to or during the pouring of the ingot, in order to remove objectionable gases, particularly hydrogen.

4.1.3 *Discard* — Sufficient discard shall be made from each ingot to secure freedom from piping and excessive segregation.

4.2 *Heat Treatment:*

4.2.1 *Preliminary Heat Treatment* — After forging and before reheating, the forgings shall be cooled to provide substantially complete transformation of austenite. Preliminary heat treatment may be applied to improve machinability and to enhance subsequent heat treatments.

4.2.2 *Heat Treatment for Mechanical Properties* — The forgings shall be heated to a temperature which produces an austenitic structure and then quenched in a suitable liquid medium by spraying or immersion. For Grade 4N; Classes 1 and 3, the austenitizing temperature shall be 1540°F [840°C] min to 1640°F [895°C] max. Quenching shall be followed by tempering at a subcritical temperature and holding at this temperature for a minimum time of one-half hour per inch of maximum section thickness. Except when Supplementary Requirement S13 is specified for Grades 2 and 3, the minimum tempering temperatures shall be as follows:

Grades 1, 1A, 2 Class 2, and 3 Class 2	1150°F [620°C]
Grades 2 Class 1 and 3 Class 1	1200°F [650°C]
Grades 4N Classes 1 and 2, and 5 Classes 1 and 2	1100°F [595°C]
Grade 4N Class 3	1125°F [600°C]
Grade 3V and 3VCb	1250°F [675°C]
Grade 22, Class 3	1200°F [650°C]

Specific cooling rates from the tempering temperature shall be applied if Supplementary Requirement S14 is specified.

4.3 For Grades 1, 1A, 2, 2A, 3, or 3A, a multiple stage austenitizing procedure may be used whereby the forging is first fully austenitized and liquid quenched, followed by reheating within the intercritical temperature range to partially reaustenitize and again liquid quenched. On completion of the austenitizing/quenching cycles, the forgings shall be tempered at a subcritical temperature as described in 4.2.2.

5. Chemical Composition

5.1 *Heat Analysis* — The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1 except that the additional features of Supplementary Requirements S7, S8, S9, and S11 shall also apply as individually specified in the ordering information.

5.2 *Product Analysis* — The manufacturer shall use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat. The permissible variations provided in Table 1 of Specification A 788 apply for manganese, nickel, chromium, molybdenum and vanadium only. Boron is not subject to product analysis. The purchaser may also make this determination in accordance with Specification A 788.

6. Mechanical Requirements

6.1 *Tension Test:*

6.1.1 The steel shall conform to the requirements of Table 2.

6.1.2 The location and number of tension test specimens for each forging or multiple forging shall be as follows:

6.1.2.1 *Multiple Forgings Separated into Identical Individual Forgings with Rough Machined Weights not Exceeding 1000 lb [455 kg] Prior to Quenching and Tempering Treatment* — At least one individual forging from each multiple forging in each heat-treating lot shall be tested using the test specimen locations of 6.1.5 or 6.1.6 as specified on the purchase orders, except that test specimens located at midlength may be closer to the ends of the production forging than the specified distance to the second surfaces. All forgings shall be quenched and tempered in the same furnace charge. All forgings from the multiple shall be Brinell hardness tested after heat treatment and forgings not tested for mechanical properties shall have a Brinell Hardness within 20 points of the Brinell Hardness of the forging that has been tested for mechanical properties.

6.1.2.2 *Forgings or Multiple Forgings (Note 2) with Rough Machined Weights Less than 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongation) of 80 in. [2032 mm] or Less* — A test prolongation (Note 3) shall be located at one end. One tension test specimen shall be taken from the test prolongation.

6.1.2.3 *Forgings or Multiple Forgings with Rough Machined Weights Less than 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongations) Exceeding 80 in. [2032 mm]* — A test prolongation shall be located at each end. One tension test specimen shall be taken from each test prolongation. An orientation of 180° shall be established between the two tension test specimens.

6.1.2.4 *Forgings or Multiple Forgings with Rough Machined Weights Over 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongation) of 80 in. [2032 mm] or Less* — A test prolongation shall be located at one end. Two tension test specimens shall be taken from the test prolongation and shall be oriented 180° apart.

6.1.2.5 *Forgings or Multiple Forgings with Rough Machined Weights Over 10 00 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongation) Exceeding 80 in. [2032 mm]* — A test prolongation shall be located at each end. The tension test specimens oriented 180° apart from each other shall be taken from each test prolongation. The two tension specimens located in one test prolongation shall be oriented 90° in relation to the two tension specimens located in the other test prolongation.

NOTE 3 — Multiple forgings in 6.1.2.2 through 6.1.2.5 are those which will be separated after the quench and temper treatment.

NOTE 4 — A test prolongation is defined as that integral test metal located at an end of the forging or forging multiples.

6.1.3 Samples for mechanical test specimen shall be removed from forgings after the quenching and tempering heat treatment. The sample material shall be subjected to a simulated post weld heat treatment if Supplementary Requirement S1 is specified.

6.1.4 For upset disk forgings, the longitudinal axis of the test specimens shall be in the tangential direction. For all other parts, the longitudinal axis of the specimens shall be parallel to the direction of major working of the forging.

6.1.5 Each forging shall be manufactured in accordance with a purchaser-approved drawing, showing the prequenched dimensions, the finished dimensions, the surfaces that will be subjected to critical stresses, and the location of mechanical test specimens.

6.1.6 The tension test specimens shall be positioned so that the longitudinal axis and mid-length is in accordance with one of the following methods:

6.1.6.1 *Method 1* — *t* by 2*t*, where *t* is the distance from the area of significant loading (see 3.1) to the nearest quenched surface. However, they shall not be nearer to one quenched surface than $\frac{3}{4}$ in. [20 mm] and to the second quenched surface than $1\frac{1}{2}$ in. [40 mm].

6.1.6.2 *Method 2* — $\frac{1}{4}$ *T* by *T*, where *T* is the maximum thickness of the forging as heat treated. Where this method of testing is employed, the following limitations for as-treated thickness shall generally apply:

Grades 1 and 1a	3 in. [75 mm], max
Grades 2 Class 2 and 3 Class 2	6 in. [150 mm],max
Grades 2 Class 1 and 3 Class 1	8 in. [205 mm], max
Grade 4N Class 2 and 5 Class 2	16 in. [405 mm], max
Grade 4N Class 1 and 5 Class 1	30 in. [760 mm], max
Grade 4N Class 3	40 in. [1015 mm], max
Grade 3V and 3VCb	20 in. [510 mm], max
Grade 22 Class 3	20 in. [510 mm], max

6.1.6.3 *Method 3* — Test specimens shall be taken from a representative separate test forging made from the same heat of steel and shall receive substantially the same reduction and type of hot working as the production forgings that it represents and shall be of the same nominal thickness as the as-quenched production forgings. The separate test forging shall be heat treated in the same furnace charge and under the same conditions as the production forgings. Test specimens shall be removed from the region midway between the mid-thickness and the surface, and not closer than *T* to a second heat treated surface with the same limitation on forging thickness as in 6.1.6.2. This method shall be limited to forgings with a rough machined weight of not more than 1000 lb [455 kg].

6.1.6.4 *Method 4* — A thermal buffer ring at least *T* by *T* in cross section, or segments of such a ring at least 3*T* in length, shall be welded to the test end of a forging prior to heat treatment for mechanical properties. The buffer material may be any weldable carbon or low-alloy steel and shall be joined to the forging with a partial-penetration type weld which completely seals the buffered surface. The test coupons shall be removed from the forging in the region buffered by the ring or ring segments. If ring segments are used, the test coupons shall be removed from the forging in the area under the buffer ring segment at a minimum distance of *T* from each end of that segment. In either case, the test specimens shall be located at a minimum distance of $\frac{1}{2}$ in. [13 mm] from the buffered surface of the forging, and at least $\frac{1}{4}$ *T* from a quenched surface of the forging.

NOTE 5 — For forgings with a maximum thickness of 2 in. [50 mm], the specimens shall be taken at mid-thickness and at least 2 in. from a second surface. This provision is applicable to all four methods in 6.1.6.

6.1.7 Tension specimens shall be the standard 0.5 in. [12.5 mm] round by 2 in. [50 mm] gage length, as shown in Test Methods and Definitions A 370.

6.2 *Impact Test:*

6.2.1 The steel shall conform to the requirements of Table 3, or Supplementary Requirement S10 may be specified instead of these requirements.

6.2.2 *Number, Location, and Orientation of Specimens:*

6.2.2.1 One set of three Charpy V-notch specimens shall be taken from each tensile specimen location required in 6.1.2. Orientation shall be the same as in 6.1.4. When S10 is specified, the required number of tests shall be governed by NB, NC, ND, NE, NF, or NG-2300, as applicable.

6.2.2.2 The requirements of 6.1.3 also apply to impact specimens.

6.2.2.3 The longitudinal axis and mid-length of the impact specimen shall be located similarly to the longitudinal axis of the tension test specimens as defined in 6.1.6. The axis of the notch shall be normal to the nearest heat-treated surface of the forging. When S10 is specified the orientation shall be governed by NB, NC, ND, NE, NF, or NG-2300.

6.2.3 Impact specimens shall be Charpy V-notch as shown in Test Methods and Definitions A 370.

7. Nondestructive Inspection Requirements

7.1 *General Requirements* — Dimensional and visual inspections, and magnetic particle and ultrasonic inspection shall be conducted by the manufacturer. Forgings shall be free of cracks, thermal ruptures, or other injurious indications.

7.2 *Magnetic Particle Inspection:*

7.2.1 Following final machining by the manufacturer all accessible surfaces of each forging shall be examined by the continuous current magnetic particle method in accordance with Test Method A 275/A 275M.

7.2.2 The following conditions are subject to rejection or removal:

7.2.2.1 Indications with major dimension exceeding $\frac{3}{16}$ in. [4.8 mm].

7.2.2.2 Four or more indications exceeding $\frac{1}{16}$ in. [1.6 mm] in major dimensions that are aligned and separated by $\frac{1}{16}$ in. [1.6 mm] or less end to end.

7.2.2.3 Ten or more indications exceeding $\frac{1}{16}$ in. [1.6 mm] in major dimensions contained in any 6 $in.^2$ [39 cm^2] of surface, with the major dimension of this area not to exceed 6 in. [150 mm]. The area shall be taken in the most unfavorable location relative to the indications being evaluated.

7.3 *Ultrasonic Inspection* — Forgings shall be ultrasonically inspected in accordance with the procedures of Practice A 388/A 388M.

7.3.1 *Longitudinal Wave Inspection:*

7.3.1.1 Unless otherwise specified by Supplementary Requirement S2, the back reflection method

of tuning shall be used in accordance with 7.2.2.1 of Practice A 388/A 388M. In addition to the reportable conditions in Section 7 of Practice A 388/A 388M, indications exceeding the resultant back reflection shall be recorded. The following conditions are considered rejectable:

7.3.1.2 Complete loss of back reflection not associated with forging configuration or surface and accompanied by an indication of a discontinuity. For this purpose, a back reflection less than 5% of full screen height shall be considered complete loss of back reflection.

7.3.1.3 Indications whose amplitude equals or exceeds that of the back reflection established in an indication-free area of the forging.

7.3.2 *Angle Beam Inspection:*

7.3.2.1 Calibration notches shall be cut into the inside and outside-diameter surfaces with a depth equal to 3% of the nominal section thickness (or $\frac{3}{8}$ in. [9.5 mm], max), a length of approximately 1 in. [25 mm], and a width not greater than twice its depth. Adjust instrument controls to obtain an indication from the inside-diameter notch approximately 75% of full screen height. Measure the amplitude of indication from the outside-diameter notch. Draw a straight line on the shield in front of the cathode ray tube from this peak to that of the inside-diameter notch and continue it as a horizontal line to the initial pulse. This line constitutes the angle beam reference line.

7.3.2.2 A forging containing a discontinuity which results in an indication exceeding the amplitude of the reference line is subject to rejection.

NOTE 6 — Signals from discontinuities within approximately $\frac{1}{4}$ in. [6.4 mm] of inside and outside surfaces are reinforced by wave trapping during angle beam inspection; they are therefore amplified in respect to internal discontinuities.

7.3.3 The report of the ultrasonic inspection shall be in compliance with Section 8 of Practice A 388/A 388M.

7.3.4 Additional nondestructive inspection or trepanning may be employed to resolve questions of interpretation of ultrasonic indications. The manufacturer shall accept responsibility for injurious indications which will not be removed in final machining.

8. Repair Welding

8.1 Repair welding of forgings may be permitted, but only at the option of the purchaser.

8.2 If repair welding is performed, welders and weld procedures shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

9. Workmanship and Quality Level Requirements

9.1 See requirements in 7.1, 7.2.2, 7.3.1.1, and 7.3.2.2.

10. Certification and Reports

10.1 In addition to items to be reported by Specification A 788, the following items shall also be reported:

10.1.1 Product chemical analysis,

10.1.2 The method used for locating test specimens, and

10.1.3 Sketches showing the locations of all recordable indications in the report of all nondestructive examinations.

10.1.4 Details of the heat treatment cycle, as listed in Specification A 788.

11. Product Marking

11.1 The purchaser may specify additional identification marking and the location of the stamping. The type of stamps to be used when impression stamping is performed shall be round-nosed or "interrupted-dot" die stamps having a minimum radius of $\frac{1}{32}$ in. [0.8 mm].

12. Keywords

12.1 chromium-molybdenum steel; nickel-chromium-molybdenum alloy steels; pressure vessel service; quenched and tempered steels; steel forgings — alloy; steel forgings — carbon; vacuum-treated steels

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %								
	Grade 1	Grade 1A	Grade 2	Grade 3	Grade 4N	Grade 5	Grade 22	Grade 3V	Grade 3VCb
Carbon	0.35 max	0.30 max	0.27 max	0.25 max	0.23 max	0.23 max	0.11–0.15	0.10–0.15	0.10–0.15
Manganese	0.40–1.05	0.70–1.35	0.50–1.00	1.20–1.50	0.20–0.40	0.20–0.40	0.30–0.60	0.30–0.60	0.30–0.60
Phosphorus	0.025 max	0.025 max	0.025 max	0.025 max	0.020 max	0.020 max	0.015 max	0.020 max	0.020 max
Sulfur	0.025 max	0.025 max	0.025 max	0.025 max	0.020 max	0.020 max	0.015 max	0.020 max	0.010 max
Silicon[1]	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40	0.30 max	0.50 max	0.10 max	0.10 max
Nickel	0.40 max	0.40 max	0.50–1.00	0.40–1.00	2.8–3.9	2.8–3.9	0.25 max	. . .	0.25 max
Chromium	0.25 max	0.25 max	0.25–0.45	0.25 max	1.5–2.00	1.5–2.00	2.00–2.50	2.8–3.3	2.7–3.3
Molybdenum	0.10 max	0.10 max	0.55–0.70	0.45–0.60	0.40–0.60	0.40–0.60	0.90–1.10 max	0.90–1.10	0.90–1.10
Vanadium	0.05 max	0.05 max	0.05 max	0.05 max	0.03 max	0.08 max	0.02 max	0.20–0.30	0.20–0.30
Columbium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.015–0.070
Copper	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.25 max
Calcium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.0005-0.0150
Boron	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.001–0.003	. . .
Titanium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.015–0.035	0.015 max

NOTE:
(1) When vacuum carbon-deoxidation is required by Supplementary Requirement S11, the silicon content shall be 0.10% maximum.

TABLE 2
TENSILE REQUIREMENTS

	Grades 1 and 1A	Grades 2 Class 1 and 3 Class 1	Grades 2 Class 2 and 3 Class 2	Grades 4N Class 1 and 5 Class 1	Grades 4N Class 2 and 5 Class 2	Grade 4N Class 3	Grade 22 Class 3	Grades 3V and 3VCb
Tensile strength, ksi [MPa]	70 to 95 [485 to 655]	80 to 105 [550 to 725]	90 to 115 [620 to 795]	105 to 130 [725 to 895]	115 to 140 [795 to 965]	90 to 115 [620 to 795]	85 to 110 [585 to 760]	85 to 110 [585 to 760]
Yield strength, min [0.2% offset], ksi [MPa]	36 [250]	50 [345]	65 [450]	85 [585]	100 [690]	70 [485]	55 [380]	60 [415]
Elongation in 2 in. or 50 mm, min, %	20	18	16	18	16	20	18	18
Reduction of area, min, %	38	38	35	45	45	48	45	45

TABLE 3
CHARPY IMPACT REQUIREMENTS

	Grades 1 and 1A (at +40°F [4.4°C])	Grades 2 Class 1 and 3 Class 1 (at +40°F [4.4°C])	Grades 2 Class 2 and 3 Class 2 (at +70°F [21°C])	Grades 4N (all classes) and 5 (all classes) (at –20°F [–29°C])	Grades 22 Classes 3, 3V, and 3VCb (at 0°F [–18°C])
Minimum average value of set of three specimens, ft·lbf (J)[1]	15[20]	30[41]	35[48]	35[48]	40[55]
Minimum value of one specimen, ft lbf (J)	10[14]	25[34]	30[41]	30[41]	35[50]

NOTE:
(1) Not more than one specimen from a set may be below this value.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Simulated Post-Weld Heat Treatment of Mechanical Test Samples

S1.1 All test coupons shall be subjected to single or multiple heat treatments at subcritical temperatures prior to testing. Such treatments are intended to simulate post-weld or other treatments to which the forgings will be subjected during subsequent fabrication. The purchaser shall furnish the manufacturer with details of the desired heat treatment for the test coupons, including temperatures, times, and cooling rates.

S2. Ultrasonic Testing-Reference Block Calibration (for examining sections 24 in. [610 mm] thick or less)

S2.1 Reference blocks of acoustically similar metal shall be used for calibration. Blocks shall meet one of the following requirements:

S2.1.1 A comparison of the back reflections between equivalent thicknesses of the reference block material and the actual forging to be tested, without change in instrument setting shall not show a variation in excess of 25%.

S2.1.2 The reference blocks shall be manufactured from steel that is similar in chemistry and processing history to the production forging being tested. The reference blocks shall be fabricated in accordance with the procedures of Practice E 428.

S2.2 For test sections up to 12 in. [305 mm] thick, the reference blocks shall contain a $\frac{1}{4}$-in. [6.4-mm] diameter flat-bottom hole; for over 12 to 18 in. [305 to 457 mm], the hole diameter shall be $\frac{3}{8}$ in. [9.5 mm]; and for over 18 to 24 in. [457 to 610 mm], it shall be $\frac{1}{2}$ in. [13 mm].

S2.3 A distance-amplitude correction curve shall be established for the proper grade of steel and specified hole size.

S2.4 A forging containing one or more indications equal in amplitude to that of the applicable reference hole, when properly corrected for distance, is subject to rejection.

S3. Charpy V-Notch Impact Transition Curve

S3.1 Sufficient impact tests shall be made from the forging test material to establish a temperature-absorbed energy curve. The test-temperature range shall be wide enough to establish the upper and lower shelf foot-pound energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

S4. Additional Charpy Data

S4.1 The percent shear fracture and mils of lateral expansion, defined in Methods and Definitions A 370, shall be reported for each Charpy specimen tested.

S5. Alternative Impact Test

S5.1 Charpy impact tests shall be made in accordance with the provisions of 6.2 of the specification except that the test temperature shall be lower than specified in Table 3. This test shall be instead of that specified in 6.2.

S6. Drop-Weight Test

S6.1 Drop-weight tests shall be conducted in accordance with the requirements of Test Method E 208. The fracture plane of the specimens shall coincide with the location required for other mechanical test specimens as specified by the purchaser in accordance with 6.1.6. However, since the drop weight specimen can be taken in any orientation, the fracture plane of the specimen when tested to Method 1 (6.1.6.1) shall be a minimum distance of $\frac{7}{16}$ in. [11 mm] from the nearest quenched surface, and $1\frac{1}{2}$ in. [38 mm] from any second surface. The purchaser may specify either duplicate no-break performance when tested 10°F [6°C] warmer than a specified temperature or request a determination of the NDT temperature.

S7. Restrictive Chemistry for Grades 4N and 5

S7.1 Phosphorus and sulfur limits for Grades 4N and 5 shall be 0.015% maximum heat and 0.018% maximum product.

S8. Additional Vanadium

S8.1 The vanadium content for Grade 5 forgings shall be 0.05 to 0.15%.

S9. Restrictive Chemistry for Grades 2, 3, or 4N

S9.1 Grades 2, 3, or 4N shall be specified with restricted phosphorus and copper limits, as follows:

S9.1.1 P 0.012 maximum heat and 0.015 maximum product; Cu 0.10 maximum and heat product, or

S9.1.2 P 0.015 maximum heat and 0.018 maximum product; Cu 0.15 maximum heat and product.

S9.2 Grades 2, 3, or 4N shall be specified with restricted sulfur of 0.015 heat and 0.018 product.

S10. Alternative Fracture Toughness Requirements

S10.1 The fracture toughness requirements (drop weight and Charpy impact tests) for materials of the ASME Boiler and Pressure Vessel Code, Section III, Articles NB-2300, NC-2300, ND-2300, NE-2300, NF-2300, or NG-2300, as specified, shall be used instead of the Charpy impact test requirements of this specification.

S11. Vacuum Carbon-Deoxidized Steels

S11.1 Material made to Grades 1, 1a, 2, 3, 4N or 5 shall be vacuum carbon-deoxidized, in which case the silicon content shall be 0.10% max. The test report shall indicate that the steel was vacuum carbon-deoxidized.

S12. Vacuum-Treated Basic Oxygen Furnace Steels

S12.1 For Grades 1, 1a, 2, or 3 material, vacuum-treated basic oxygen furnace steel shall be used.

S13. Minimum Tempering Temperature

S13.1 For Grades 2 Class 1 and 3 Class 1 the minimum tempering temperature shall be 1175°F [635°C] and the simulated post weld heat treatment temperature shall not exceed 1150°F [620°C] when S1 is required.

S14. Cooling from the Tempering Temperature

S14.1 The purchaser shall provide specific cooling rates from the tempering temperature.

S15. Product Analysis

S15.1 More than one forging per heat shall be subject to product analysis by either the manufacturer or purchaser. The purchaser shall indicate in the ordering information the number of forgings to be tested, and whether the manufacturer, purchaser, or both shall perform the additional analyses.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, FOR INTERMEDIATE- AND HIGHER-TEMPERATURE SERVICE

SA-515/SA-515M

(Identical with ASTM Specification A 515/A 515M-92.) 98

1. Scope

1.1 This specification covers carbon-silicon steel plates primarily for intermediate- and higher-temperature service in welded boilers and other pressure vessels.

1.2 Material under this specification is available in four grades having different strength levels as follows:

Grade U.S. [SI]	Tensile Strength, ksi [MPa]
60 [415]	60–80 [415–550]
65 [450]	65–85 [450–585]
70 [485]	70–90 [485–620]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

Grade U.S. [SI]	Maximum Thickness, in. [mm]
60 [415]	8 [200]
65 [450]	8 [200]
70 [485]	8 [200]

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Document

2.1 *ASTM Standard:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and made to a coarse austenitic grain size practice.

5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 2 in. [50 mm] in thickness shall be normalized.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %		
	Grade 60 [Grade 415]	Grade 65 [Grade 450]	Grade 70 [Grade 485]
Carbon, max[A]:			
1 in. [25 mm] and under	0.24	0.28	0.31
Over 1 to 2 in. [25 to 50 mm], incl	0.27	0.31	0.33
Over 2 to 4 in. [50 to 100 mm], incl	0.29	0.33	0.35
Over 4 to 8 in. [100 to 200 mm], incl	0.31	0.33	0.35
Over 8 in. [200 mm]	0.31	0.33	0.35
Manganese, max:			
Heat analysis	0.90	0.90	1.20
Product analysis	0.98	0.98	1.30
Phosphorus, max[A]	0.035	0.035	0.035
Sulfur, max[A]	0.035	0.035	0.035
Silicon:			
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45

[A] Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

	Grade		
	60 [415]	65 [450]	70 [485]
Tensile strength, ksi [MPa]	60–80 [415–550]	65–85 [450–585]	70–90 [485–620]
Yield strength, min, ksi [MPa]	32 [220]	35 [240]	38 [260]
Elongation in 8 in. [200 mm], min, %	21[A]	19[A]	17[A]
Elongation in 2 in. [50 mm], min, %	25[A]	23[A]	21[A]

[A] See Specification A 20/A 20M.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in ASTM Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop-Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435 M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below is an additional optional supplementary requirement suitable for this specification:

S61. Austenitic Grain Size

S61.1 The material shall have a carburized austenitic grain size of 1 to 5.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, FOR MODERATE- AND LOWER-TEMPERATURE SERVICE

SA-516/SA-516M

(Identical with ASTM Specification A 516/A 516M-90.)

1. Scope

1.1 This specification covers carbon steel plates intended primarily for service in welded pressure vessels where improved notch toughness is important.

1.2 Plates under this specification are available in four grades having different strength levels as follows:

Grade U.S. [SI]	Tensile Strength, ksi [MPa]
55 [380]	55–75 [380–515]
60 [415]	60–80 [415–550]
65 [450]	65–85 [450–585]
70 [485]	70–90 [485–620]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

Grade U.S. [SI]	Maximum Thickness, in. [mm]
55 [380]	12 [305]
60 [415]	8 [205]
65 [450]	8 [205]
70 [485]	8 [205]

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 Plates 1.50 in. [40 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 1.50 in. [40 mm] in thickness shall be normalized.

5.3 When notch-toughness tests are required on plates $1\frac{1}{2}$ in. [40 mm] and under in thickness, the plates shall be normalized unless otherwise specified by the purchaser.

5.4 If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible for improvement of the toughness, provided the plates are subsequently tempered in the temperature range 1100 to 1300°F [595 to 705°C].

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %			
	Grade 55 [Grade 380]	Grade 60 [Grade 415]	Grade 65 [Grade 450]	Grade 70 [Grade 485]
Carbon, max[A]:				
½ in. [12.5 mm] and under	0.18	0.21	0.24	0.27
Over ½ in. to 2 in. [12.5 to 50 mm], incl	0.20	0.23	0.26	0.28
Over 2 in. to 4 in. [50 to 100 mm], incl	0.22	0.25	0.28	0.30
Over 4 to 8 in. [100 to 200 mm], incl	0.24	0.27	0.29	0.31
Over 8 in. [200 mm]	0.26	0.27	0.29	0.31
Manganese:				
½ in. [12.5] and under:				
Heat analysis[B]	0.60–0.90	0.60–0.90	0.85–12.0	0.85–1.20
Product analysis[B]	0.55–0.98	0.55–0.98	0.79–1.30	0.79–1.30
Over ½ in. [12.5]:				
Heat analysis	0.60–1.20	0.85–1.20	0.85–1.20	0.85–1.20
Product analysis	0.55–1.30	0.79–1.30	0.79–1.30	0.79–1.30
Phosphorus, max[A]	0.035	0.035	0.035	0.035
Sulfur, max[A]	0.035	0.035	0.035	0.035
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45

[A] Applies to both heat and product analyses.
[B] Grade 60 plates ½ in. [12.5 mm] and under in thickness may have 0.85–1.20% manganese on heat analysis, and 0.79–1.30% manganese on product analysis.

TABLE 2
TENSILE REQUIREMENTS

	Grade			
	55 [380]	60 [415]	65 [450]	70 [485]
Tensile strength, ksi [MPa]	55–75 [380–515]	60–80 [415–550]	65–85 [450–585]	70–90 [485–620]
Yield strength, min,[B] ksi [MPa]	30 [205]	32 [220]	35 [240]	38 [260]
Elongation in 8 in. [200 mm], min, %	23[A]	21[A]	19[A]	17[A]
Elongation in 2 in. [50 mm], min, %	27[A]	25[A]	23[A]	21[A]

[A] See Specification A 20/A 20M.
[B] Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in ASTM Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop-Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, HIGH-STRENGTH, QUENCHED AND TEMPERED

SA-517/SA-517M

(Identical with ASTM Specification A 517/A 517M-93 for Grades A, B, E, F, J, P except for the deletion of fusion in 1.1.)

1. Scope

1.1 This specification covers high-strength quenched and tempered alloy steel plates intended for use in welded boilers and other pressure vessels.

1.2 This specification includes a number of grades as manufactured by different producers, but all having the same mechanical properties and general characteristics.

1.3 The maximum thickness of plates furnished under this specification shall be as follows:

Grade	Thickness
A, B, J	1.25 in. [32 mm]
P	4 in. [100 mm]
F	2.50 in. [65 mm]
E	6 in. [150 mm]

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information which should be complied with when purchasing material to this specification.

3.3 In addition the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be heat treated by the material manufacturer by heating to not less than 1650°F [900°C], quenching in water or oil and tempering at not less than 1150°F [900°C] for not less than ½ h.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M for grades other than Grade A.

7. Mechanical Requirements

7.1 *Tensions:*

7.1.1 *Requirements*—The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.1.2 *Test Methods:*

7.1.2.1 The yield strength may be determined by the 0.2% offset method or by the total extension under load of 0.5% method.

7.1.2.2 For material ¾ in. [20 mm] and under in thickness, the test specimen shall be the 1½ in. [40 mm] wide rectangular-test specimen.

7.1.2.3 For material over ¾ in. [20 mm], either the full thickness rectangular-test specimen or the ½ in. [12.5 mm] round-test specimen may be used.

7.1.2.4 When the 1½ in. [40 mm] wide rectangular-test specimen is used, the elongation is measured in a 2 in. [50 mm] gage length which includes the fracture.

7.2 *Impact Properties Requirements:*

7.2.1 Transverse Charpy V-notch impact test specimens shall have a lateral expansion opposite the notch of not less that 0.015 in. [0.38 mm].

7.2.2 The test temperature shall be agreed upon between the manufacturer and the purchaser, but shall not be higher than 32°F [0°C].

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %					
	Grade A	Grade B	Grade E	Grade F	Grade J	Grade P
Carbon:						
Heat analysis	0.15–0.21	0.15–0.21	0.12–0.20	0.10–0.20	0.12–0.21	0.12–0.21
Product Analysis	0.13–0.23	0.13–0.23	0.10–0.22	0.08–0.22	0.10–0.23	0.10–0.23
Manganese:						
Heat analysis	0.80–1.10	0.70–1.00	0.40–0.70	0.60–1.00	0.45–0.70	0.45–0.70
Product analysis	0.74–1.20	0.64–1.10	0.35–0.78	0.55–1.10	0.40–0.78	0.40–0.78
Phosphorus, max[A]	0.035	0.035	0.035	0.035	0.035	0.035
Sulfur, max[A]	0.035	0.035	0.035	0.035	0.035	0.035
Silicon:						
Heat analysis	0.40–0.80	0.15–0.35	0.10–0.40	0.15–0.35	0.20–0.35	0.20–0.35
Product analysis	0.34–0.86	0.13–0.37	0.08–0.45	0.13–0.37	0.18–0.37	0.18–0.37
Nickel:						
Heat analysis	. . .	. . .	. . .	0.70–1.00	. . .	1.20–1.50
Product analysis	. . .	. . .	. . .	0.67–1.03	. . .	1.15–1.55
Chromium:						
Heat analysis	0.50–0.80	0.40–0.65	1.40–2.00	0.40–0.65	. . .	0.85–1.20
Product analysis	0.46–0.84	0.36–0.69	1.34–2.06	0.36–0.69	. . .	0.79–1.26
Molybdenum:						
Heat analysis	0.18–0.28	0.15–0.25	0.40–0.60	0.40–0.60	0.50–0.65	0.45–0.60
Product analysis	0.15–0.31	0.12–0.28	0.36–0.64	0.36–0.64	0.46–0.69	0.41–0.64
Boron	0.0025 max	0.0005–0.005	0.001–0.005	0.0005–0.006	0.001–0.005	0.001–0.005
Vanadium:						
Heat analysis	. . .	0.03–0.08	[B]	0.03–0.08	. . .	. . .
Product analysis	. . .	0.02–0.09	. . .	0.02–0.09	. . .	. . .
Titanium:						
Heat analysis	. . .	0.01–0.03	0.01–0.10	. . .	. . .	. . .
Product analysis	. . .	0.01–0.04	0.005–0.11	. . .	. . .	. . .
Zirconium:						
Heat analysis	0.05[C]–0.15	. . .	. . .	. . .	. . .	. . .
Product analysis	0.04–0.16	. . .	. . .	. . .	. . .	. . .
Copper:						
Heat analysis	. . .	. . .	. . .	0.15–0.50	. . .	. . .
Product analysis	. . .	. . .	. . .	0.12–0.53	. . .	. . .
Columbium, max						
Heat analysis	. . .	. . .	. . .	. . .	. . .	. . .
Product analysis	. . .	. . .	. . .	. . .	. . .	. . .

[A] Applied to both heat and product analyses.
[B] May be substituted for part or all of titanium content on a one for one basis.
[C] Zirconium may be replaced by cerium. When cerium is added, the cerium/sulfur ration should be approximately 1.5 to 1, based on heat analysis.

TABLE 2
TENSILE REQUIREMENTS

	2.50 in. [65 mm] and Under	Over 2.50 to 6 in. [65 to 150 mm]
Tensile strength, ksi [MPa]	115–135 [795–930]	105–135 [725 to 930]
Yield strength, min, ksi [MPa]	100 [690]	90 [620]
Elongation in 2 in. [50 mm], min, %	16	14
Reduction of area, min, %:		
Rectangular specimens	35	. . .
Round specimens	45	45

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in ASTM Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Test,

S6. Drop-Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435 M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR FORGED OR ROLLED 8 AND 9% NICKEL ALLOY STEEL FLANGES, FITTINGS, VALVES, AND PARTS FOR LOW-TEMPERATURE SERVICE

SA-522/SA-522M

(Identical with ASTM Specification A 522/A 522M-95.) 98

1. Scope

1.1 This specification covers 8 and 9% nickel-alloy steel forged or rolled flanges, fittings, valves, and parts intended for use in welded pressure vessels for low-temperature service. The specification is applicable to forgings with maximum section thickness of 3 in. [75 mm] in the double normalized and tempered condition and 5 in. [125 mm] in the quenched and tempered condition. Forgings under this specification are intended for service at operating temperatures not lower than −320°F [−196°C] for Type I or −275°F [−170°C] for Type II or higher than 250°F [121°C].

1.2 Material under this specification is available in two types having different chemical compositions as follows:

Type	Nominal Nickel Content, %
I	9
II	8

1.3 Supplementary requirements S1 and S2 are optional and shall apply when specified by the purchaser.

1.4 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 788 Specification for Steel Forgings, General Requirements

2.2 *Other Standard:*

AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following: 98

3.1.1 Quantity,

3.1.2 Size and pressure class or dimensions (Tolerances and surface finishes should be included),

3.1.3 Specification number and type (The year date should be included),

3.1.4 Supplementary requirements, and

3.1.5 Additional requirements, (See 4.4, 11.6, 16.1, 17.1, 17.2, and 18.3).

4. Materials and Manufacture

4.1 The steel shall be produced in accordance with the melting process section of Specification A 788.

4.2 Material for forgings shall consist of ingots, or either forged or rolled blooms, billets, or bars.

4.3 The finished product shall be a forging as defined in the Terminology Section of Specification A 788.

4.4 When specified in the order, the manufacturer shall submit for purchaser's approval a sketch showing the shape of the rough forging before machining.

5. Chemical Composition

5.1 The steel shall conform to the requirements for chemical composition as prescribed in Table 1. Test Methods, Practices, and Terminology A 751 shall apply.

6. Tensile Requirements

6.1 The forgings shall conform to the tensile property requirements prescribed in Table 2.

6.2 The forgings shall be tested in accordance with the latest issue of Test Methods and Definitions A 370.

7. Impact Requirements

7.1 Impact tests shall be conducted at −320°F [−195°C] for Type I and at −275°F [−170°C] for Type II, except when a higher temperature is specified in accordance with Supplementary Requirement S2. Each test shall consist of three specimens and each specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. [15 mils] [0.38 mm].

7.2 The values of energy absorption in footpounds (or joules) and the fracture appearance in percent shear shall be recorded and reported for information.

8. Heat Treatment

8.1 The forgings shall be heat treated by the manufacturer by either of the following methods as mutually agreed upon between the purchaser and the manufacturer.

8.1.1 *Quenched and Tempered*—Heat to a uniform temperature of 1475 ± 25°F [800 ± 15°C]; hold at this temperature for a minimum time of 1 h/in. (2.4 min/mm) of thickness but in no case less than 30 min; quench by immersion in circulating water. Reheat until the forging attains a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. of thickness but in no case less than 30 min; cool in air or water quench, at a rate not less than 300°F [165°C]/h.

8.1.2 *Double Normalized and Tempered*—Heat to a uniform temperature of 1650°F [900°C]; hold at this temperature for a minimum time of 1 h/in. (2.4 min/mm) of thickness but in no case less than 30 min; cool in air. Reheat until the forging attains a uniform temperature of 1450°F [790°C]; hold at this temperature for a minimum time of 1 h/in. of thickness but in no case less than 30 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. of thickness but in no case less than 30 min; cool in air or water quench, at a rate not less than 300°F [165°C]/h.

8.2 When stress relieving is to be performed after fabrication, the recommended stress-relieving treatment is as follows: gradually and uniformly heat the steel to a temperature between 1025 and 1085°F [550 and 585°C]; hold for a minimum of 2 h for thicknesses up to 1 in. [25 mm]. For thicknesses over 1 in. [25 mm], a minimum additional holding time in the ratio of 1 h/in. (2.4 min/mm) of thickness in excess of 1 in. [25 mm] shall be added. Cool at a minimum rate of 300°F [165°C]/h to a temperature not exceeding 600°F [315°C].

9. Cast or Heat (Formerly Ladle) Analysis

9.1 An analysis of each heat of steel shall be made by the manufacturer to determine percentages of the elements specified in Table 1.

10. Product (Check) Verification Analysis

10.1 An analysis may be made by the purchaser from a forging representing each heat. Samples for

analysis shall be taken not less than $\frac{1}{4}$ in. [6 mm] below the surface of the forgings, or from tension test specimens. The chemical composition thus determined shall conform to the requirements specified in Table 1.

11. Test Specimens

11.1 The tension and impact specimens may be obtained from a rough or finished production forging, or prolongation thereof, or from special forged blocks, suitably worked and heat treated with the production forgings. These tension and impact tests may represent all forgings from the same heat and heat treatment charge, provided the maximum thickness of such forgings is not greater than the thickness of the test forging, prolongation, or special test block. Such special test blocks shall be forged in a manner similar to and shall have a maximum reduction not greater than the forgings represented. The manufacturer shall provide the required extra forgings or test blocks.

11.2 The test specimens shall be located at any point midway between the center and surface of solid forgings, and at any point midthickness of the heaviest section of hollow or bored forgings. For solid forgings where test metal is provided on the periphery, test specimens shall be taken at mid-thickness of the test prolongation.

11.3 Tests shall be oriented so that the longitudinal axis of the specimen is parallel to the major direction of grain flow.

11.4 The tension test specimens shall be machined to the standard specimen form and dimensions shown in Fig. 4 of Test Methods and Definitions A 370. In the case of sections too small to accommodate the standard specimen, the largest practicable small-size specimen shown in Fig. 4 of Test Methods and Definitions A 370 shall be used.

11.5 Standard Charpy V-notch specimens in accordance with Fig. 10 of Test Methods and Definitions A 370 shall be used, except where the material is of insufficient thickness to permit their use, in which case the largest obtainable specimens shown in 20.2.2 of Test Methods and Definitions A 370 shall be used.

11.6 When fabrication requires stress relieving, the purchaser shall specify stress relieving of the test pieces prior to machining of the test specimens. Stress relieving shall be carried out as prescribed in 8.2.

12. Method of Impact Testing

12.1 The impact test shall be made in accordance with the simple beam, Charpy type of test described in the latest issue of Test Methods and Definitions A 370.

12.2 Precaution shall be taken so that when broken, the test specimens shall be within ±3°F [1.7°C] of the specified test temperature.

13. Workmanship, Finish, and Appearance

13.1 The forgings shall have a workman-like finish and shall be free of injurious defects.

14. Number of Tests and Retests

14.1 At least one tension test and one set of impact tests (three specimens) shall be made from each heat in each heat-treatment charge, subject to the provisions of 11.5.

14.2 If any test specimens fail due to mechanical causes, such as testing-equipment failure or improper specimen preparation, the specimens may be discarded and replacement specimens shall be considered as original tests.

14.3 If the results of the mechanical tests do not conform to the specified requirements, the manufacturer may retreat the forgings, but not more than three additional times. Retests shall be made in accordance with this section.

14.4 If the percentage elongation of any tension test specimen is less than that prescribed in Table 2 and any part of the fracture is outside the middle half of the gage length, a retest shall be allowed.

14.5 If the results of mechanical tests do not conform to the specified requirements because a flaw develops in the test specimen, a retest shall be allowed if the defect is not caused by ruptures, cracks, or flakes in the steel.

14.6 If the result from a test on one Charpy impact specimen from a set is below 0.015 in. [0.38 mm] in lateral expansion but not below 0.010 in. [0.25 mm] and the average test result on the set of specimens equals or exceeds 0.015 in. [0.38 mm], one retest of three additional specimens may be made. Each of the test results on the retested specimens shall equal or exceed 0.015 in. [0.38 mm].

15. Inspection

15.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

15.2 The manufacturer shall report to the purchaser or the purchaser's representative the heat treatments applied to the material and to the test blocks and the results of the chemical analysis and mechanical tests made in accordance with this specification and the heat number or his heat identification.

16. Rejection

16.1 Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported to the manufacturer within 60 days from the receipt of samples or test reports by the purchaser.

16.2 Each forging in which injurious metal defects are exposed during subsequent machining shall be rejected and the manufacturer notified.

17. Certification

17.1 For forgings made to specified dimensions, when agreed upon by the purchaser, and for forgings made to dimensional standards unless written certification is required by the purchaser, the application of identification marks as required in Section 18 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification.

17.2 Test reports, when required, shall include certification that all requirements of this specification have been met. The manufacturer shall provide the following where applicable:

17.2.1 Whether Type 1 or Type 11 material has been supplied and the chemical analysis results in accordance with Section 6,

17.2.2 Type of heat treatment used,

17.2.3 Results of tension and Charpy impact tests including the impact test temperature, and test coupon stress relief details if applicable,

17.2.4 Results of any additional or supplementary requirements specified by the purchaser, and

17.2.5 The year date and revision letter, if any, of the specification. Note, this information is not required to be marked on the forgings.

18. Product Marking

18.1 Each forging shall be legibly stamped by the manufacturer with the heat number or his heat identification, the manufacturer's name (Note) or trademark, and this specification number, A 522/A 522M, 8NI, or 9NI as applicable, and QT or NNT as applicable.

NOTE—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

18.2 Forgings impact tested at temperatures other than that specified in 7.1 shall be marked with the letters LTV following the specification number. These letters shall be followed by the impact test temperature in degrees Fahrenheit. A prefix 0 to the test temperature indicates a temperature below 0°F [−17.8°C], for example LTV0300 indicates −300°F [−184°C].

18.3 The purchaser may specify additional identification marking and the location of all stamping. The type of stamps shall be round or "interrupted-dot" die stamps having a radius of $^{1}/_{32}$ in. [0.8 mm].

18.4 *Bar Coding*—In addition to the requirements in 18.1, 18.2, and 18.3, bar coding is acceptable as a supplementary identification method, Bar coding should be consistent with the AIAG standard B-5 02.00. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %	
	Type I	Type II
Carbon, max	0.13	0.13
Manganese, max	0.90	0.90
Phosphorus, max		
Heat analysis	0.025	0.025
Product analysis	0.030	0.030
Sulfur, max	0.025	0.025
Silicon[A]		
Heat analysis	0.15–0.30	0.15–0.30
Product analysis	0.13–0.32	0.13–0.32
Nickel		
Heat analysis	8.50–9.50	7.50–8.50
Product analysis	8.40–9.60	7.40–8.60

[A] When vacuum carbon deoxidation is used, the maximum silicon content shall be 0.10%.

TABLE 2
TENSILE REQUIREMENTS AT ROOM TEMPERATURE

Tensile strength, min, ksi [MPa]	100 [690]
Yield strength, min, (0.2% off-set), ksi [MPa]	75 [515]
Elongation in 2 in. [50 mm], min, %	22
Reduction of area, min, %	45

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below may be included in purchaser's order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S1. Nondestructive Tests

S1.1 *Ultrasonic Tests*—Ultrasonic tests may be made by agreement between manufacturer and purchaser.

S1.2 *Liquid Penetrant Tests*—Liquid penetrant tests may be made by agreement between manufacturer and purchaser.

S2. Other Impact Test Temperatures

S2.1 The purchaser may specify an impact test temperature higher than that in 7.1 but no higher than the minimum intended operating temperature for the forging.

S2.2 Marking shall be in accordance with 18.2.

SPECIFICATION FOR SEAMLESS CARBON STEEL PIPE FOR ATMOSPHERIC AND LOWER TEMPERATURES

SA-524

(Identical with ASTM Specification A 524-93.) 98

1. Scope

1.1 This specification covers seamless carbon steel pipe intended primarily for service at atmospheric and lower temperatures, NPS $\frac{1}{8}$ to 26 inclusive, with nominal (average) wall thickness as given in ANSI B36.10. Pipe having other dimensions may be furnished, provided such pipe complies with all other requirements of this specification. Pipe ordered to this specification shall be suitable both for welding, and for bending, flanging, and similar forming operations.

1.2 The values stated in inch-pound units are to be regarded as the standard.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size".

1.3 The following hazard caveat applies to the test methods portion, Section 12, only. *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *American National Standards Institute Standard:*

B36.10 Welded and Seamless Wrought Steel Pipe

3. General Requirements

3.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet or number of lengths),

4.1.2 Name of material (seamless carbon steel pipe),

4.1.3 Grade (Tables 1 and 2),

4.1.4 Manufacture (hot finished or cold drawn),

4.1.5 Size (either nominal wall thickness and weight class or schedule number, or both, or outside diameter and nominal wall thickness, ANSI B36.10),

4.1.6 Length (Section 16),

4.1.7 Optional requirements (Section 8, Section 11, and Section 17 of Specification A 530/A 530M),

4.1.8 Test report required (Certification Section of Specification A 530/A 530M),

4.1.9 Specification designation,

4.1.10 End use of material, and

4.1.11 Special requirements.

5. Materials and Manufacture

5.1 *Process:*

5.1.1 The steel shall be killed steel made by one or more of the following processes: open-hearth, electric-furnace, or basic-oxygen.

5.1.2 The steel shall be made to fine grain practice.

5.1.3 Steel may be cast in ingots or may be strand cast. When steel of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

5.1.4 Pipe NPS 1½ and under may be either hot finished or cold drawn.

5.1.5 Unless otherwise specified, pipe NPS 2 and over shall be furnished hot finished. When agreed upon between the manufacturer and purchaser, cold-drawn pipe may be furnished.

5.2 *Heat Treatment:*

5.2.1 All hot-finished and cold-drawn pipe shall be reheated to a temperature above 1550°F (845°C) and followed by cooling in air or in the cooling chamber of a controlled atmosphere furnace.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements prescribed in Table 1.

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified in Section 6. The chemical composition thus determined, or that determined from a product analysis made by the manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 6.

8. Product Analysis

8.1 At the request of the purchaser, analyses of two pipes from each lot (Note 2) shall be made by the manufacturer from the finished pipe. The chemical composition thus determined shall conform to the requirements specified in Section 6.

NOTE 2 — A lot shall consist of 400 lengths, or fraction thereof, for each size NPS 2 up to but not including NPS 6, and of 200 lengths, or fraction thereof, for each size NPS 6 and over.

8.2 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in Section 6, analyses shall be made on additional pipe of double the original number from the same lot, each of which shall conform to requirements specified.

9. Physical Properties

9.1 *Tensile Properties* — The material shall conform to the requirements as to tensile properties prescribed in Table 2.

9.2 *Bending Properties:*

9.2.1 For pipe NPS 2 and under, a sufficient length of pipe shall stand being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the nominal diameter of the pipe, without developing cracks. When ordered for close coiling, the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the nominal diameter of the pipe, without failure.

9.2.2 For pipe whose diameter exceeds 25 in. (635 mm) and whose diameter to wall thickness ratio is 7.0 or less, bend test specimens shall be bent at room temperature through 180° without cracking on the outside of the bent portion. The inside diameter of the bend shall be 1 in. (25.4 mm). This test shall be in place of Section 10.

NOTE 3 — Diameter to wall thickness ration = specified outside diameter/nominal wall thickness.
Example: For 28 in. diameter 5.000 in. thick pipe the diameter to wall thickness ratio = 28/5 = 5.6.

10. Flattening Test Requirements

10.1 For pipe over NPS 2, a section of pipe not less than 2½ in. (63.5 mm) in length shall be flattened cold between parallel plates until the opposite walls of the pipe meet. Flattening tests shall be in accordance with Specification A 530, except that in the equation

used to calculate the *H* value, the following *e* constants shall be used:

0.07 for Grade I
0.08 for Grade II

10.2 When low *D*-to-*t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than 10.

11. Hydrostatic Test Requirements

11.1 Each length of pipe shall be subjected to the hydrostatic pressure, except as provided in 11.2.

11.2 When specified in the order, pipe may be furnished without hydrostatic testing and each length so furnished shall include with the mandatory marking the letters "NH."

11.3 When certification is required by the purchaser and the hydrostatic test has been omitted, the certification shall clearly state "Not Hydrostatically Tested," and the specification number and grade designation, as shown on the certification, shall be followed by the letters "NH."

12. Test Specimens and Methods of Testing

12.1 Specimens cut either longitudinally or transversely shall be acceptable for the tension test.

12.2 Test specimens for the bend test specified in 9.2 and for the flattening tests specified in Section 10 shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends.

12.3 Test specimens for the bend test specified in 9.2.2 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either ½ by ½ in. (12.7 mm) in section or 1 by ½ in. (25.4 by 12.7 mm) in section with the corners rounded to a radius not over 1/16 in. (1.6 mm) and need not exceed 6 in. (152 mm) in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe respectively.

13. Number of Tests and Retests

13.1 One of either of the tests specified in 9.1 shall be made on one length of pipe from each lot (Note 2).

13.2 For pipe NPS 2 and under, the bend test specified in 9.2 shall be made on one pipe from each lot (Note 2). The bend tests specified in 9.2.2 shall be made on one end of each pipe.

13.3 The flattening test specified in Section 10 shall be made on one length of pipe from each lot (Note 2).

13.4 Retests shall be in accordance with Specification A 530 and as provided in 13.5 and 13.6.

13.5 If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

13.6 Should a crop end of a finished pipe fail in the flattening test, one retest may be made from the broken end.

14. Dimensions and Weights

14.1 The dimensions and weights of plain-end pipe are included in ANSI B36.10. Sizes and wall thicknesses most generally available are listed in Appendix, Table X1.2.

15. Dimensions, Weight, and Permissible Variations

15.1 *Weight* — The weight of any length of pipe shall not vary more than 6.5% over and 3.5% under that specified for pipe of Schedule 120 and lighter nor more than 10% over and 3.5% under that specified for pipe heavier than Schedule 120. Unless otherwise agreed upon between the manufacturer and purchaser, pipe in sizes NPS 4 and smaller may be weighed in convenient lots; pipe in sizes larger than NPS 4 shall be weighed separately.

15.2 *Diameter* — Variations in outside diameter shall not exceed those specified in Table 3.

15.3 *Thickness* — The minimum wall thickness at any point shall not be more than 12.5% under the nominal wall thickness specified.

NOTE 4 — The minimum wall thickness on inspection is shown in Appendix, Table X1.1.

16. Lengths

16.1 Pipe lengths shall be in accordance with the following regular practice:

16.1.1 The lengths required shall be specified in the order, and

16.1.2 No jointers are permitted unless otherwise specified.

16.2 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft (4.9 to 6.7 m), with 5% 12 to 16 ft (3.7 to 4.9 m), or in double random lengths with a minimum average of 35 ft (10.7 m) and a minimum length of 22 ft with 5% 16 to 22 ft.

17. Workmanship, Finish, and Appearance

17.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to assure compliance with 17.2.

17.2 Surface imperfections that penetrate more than $12\frac{1}{2}$% of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

17.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

17.2.2 Repaired in accordance with the repair welding provisions of 17.6.

17.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

17.2.4 Rejected.

17.3 To provide a workmanlike finish and basis for evaluating conformance with 17.2, the pipe manufacturer shall remove by grinding the following noninjurious imperfections:

17.3.1 Mechanical marks, abrasions (Note 5) and pits, any of which imperfections are deeper than $\frac{1}{16}$ in. (1.58 mm).

NOTE 5 — Marks and abrasions are defined as cable marks, dinges, guide marks, roll marks, ball scratches, scores, die marks, and the like.

17.3.2 Visual imperfections, commonly referred to as scabs, seams, laps, tears or slivers, found by exploration in accordance with 17.1 to be deeper than 5% of the nominal wall thickness.

17.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 17.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

17.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

17.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

17.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

17.7 The finished pipe shall be reasonably straight.

18. Rejection

18.1 Each length of pipe that develops injurious defects during shop working or application operations will be rejected, and the manufacturer shall be notified. No rejections under this or any other specifications shall be marked as specified in Section 19 for sale under this specification except where such pipe fails to comply with the weight requirements alone, in which case it may be sold under the weight specifications with which it does comply.

19. Product Marking

19.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include the hydrostatic test pressure when tested or the letters "NH" when not tested, the length and schedule number, and on pipe sizes larger than NPS 4 the weight shall be given. Length shall be marked in feet and tenths of a foot, or metres to two decimal places, depending on the units to which the material was ordered, or other marking subject to agreement.

19.2 *Bar Coding* — In addition to the requirements in 19.1, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Grades I and II, Composition, %
Carbon, max	0.21
Manganese	0.90–1.35
Phosphorus, max	0.035
Sulfur, max	0.035
Silicon	0.10–0.40

TABLE 2
TENSILE REQUIREMENTS

	Wall Thicknesses			
	Grade I, 0.375 in. (95.2 mm) and under		Grade II, greater than 0.375 in. (95.2 mm)	
Tensile strength, psi (MPa)	60 000–85 000 (414–586)		55 000–80 000 (380–550)	
Yield strength, min, psi (MPa)	35 000 (240)		30 000 (205)	
	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. or 50 mm, min, %:				
Basic minimum elongation for walls $^{5}/_{16}$ in. (7.9 mm) and over in thickness, strip tests, and for all small sizes tested in full section	30	16.5	35	25
When standard round 2 in. or 50 mm gage length test specimen is used for strip tests, a deduction for each $^{1}/_{32}$ in. (0.8 mm) decrease in wall thickness below $^{5}/_{16}$ in. (7.9 mm) from the basic minimum elongation of the following percentage	22 1.50[A]	12 1.00[A]	28 . . .	20 . . .

[A] The following table gives the computed minimum values:

Wall Thickness		Elongation in 2 in. or 50 mm, min, %	
		Grade I	
in.	mm	Longitudinal	Transverse
$^{5}/_{16}$ (0.312)	7.94	30.0	16.5
$^{9}/_{32}$ (0.281)	7.14	28.5	15.5
$^{1}/_{4}$ (0.250)	6.35	27.0	14.5
$^{7}/_{32}$ (0.219)	5.56	25.5	. . .
$^{3}/_{16}$ (0.188)	4.76	24.0	. . .
$^{5}/_{32}$ (0.156)	3.97	22.5	. . .
$^{1}/_{8}$ (0.125)	3.18	21.0	. . .
$^{3}/_{32}$ (0.094)	2.38	19.5	. . .
$^{1}/_{18}$ (0.062)	1.59	18.0	. . .

NOTE — The above table gives the computer minimum elongation values for each $^{1}/_{32}$ in. (0.79 mm) decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

Grade	Direction of Test	Equation
I	transverse	$E = 32t + 6.50$
I	longitudinal	$E = 48t + 15.00$

where:
E = elongation in 2 in. or 50 mm in % and
t = actual thickness of specimen, in. (mm)

TABLE 3
VARIATIONS IN OUTSIDE DIAMETER

	Permissible Variations in Outside Diameter, in. (mm)	
NPS Designator	Over	Under
$^{1}/_{8}$ to $1^{1}/_{2}$, incl	$^{1}/_{64}$ (0.4)	$^{1}/_{32}$ (0.8)
Over $1^{1}/_{2}$ to 4, incl	$^{1}/_{32}$ (0.8)	$^{1}/_{32}$ (0.8)
Over 4 to 8, incl	$^{1}/_{16}$ (1.6)	$^{1}/_{32}$ (0.8)
Over 8 to 18, incl	$^{3}/_{32}$ (2.4)	$^{1}/_{32}$ (0.8)
Over 18	$^{1}/_{8}$ (3.2)	$^{1}/_{32}$ (0.8)

APPENDIX

(Nonmandatory Information)

TABLE X1.1
TABLE OF MINIMUM WALL THICKNESSES ON INSPECTION FOR NOMINAL (AVERAGE) PIPE WALL THICKNESS

NOTE 1 — The following equation, upon which this table is based, may be applied to calculated minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:
t_n = nominal (average) wall thickness, in. (mm), and
t_m = minimum wall thickness, in. (mm).

The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped, in accordance with Practice E 29.

NOTE 2 — This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)	
in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.068	1.73	0.060	1.52	0.281	7.14	0.246	6.25	0.864	21.94	0.756	19.20
0.083	2.11	0.073	1.85	0.294	7.47	0.257	6.53	0.875	22.22	0.766	19.46
0.088	2.24	0.077	1.96	0.300	7.62	0.262	6.65	0.906	23.01	0.793	20.14
0.091	2.31	0.080	2.03	0.307	7.80	0.269	6.83	0.938	23.82	0.821	20.85
0.095	2.41	0.083	2.11	0.308	7.82	0.270	6.86	0.968	24.59	0.847	21.51
0.109	2.77	0.095	2.41	0.312	7.92	0.273	6.93	1.000	25.40	0.875	22.22
0.113	2.87	0.099	2.51	0.318	8.07	0.278	7.06	1.031	26.19	0.902	22.91
0.119	3.02	0.104	2.64	0.322	8.18	0.282	7.16	1.062	26.97	0.929	23.60
0.125	3.18	0.109	2.77	0.330	8.38	0.289	7.34	1.094	27.79	0.957	24.31
0.126	3.20	0.110	2.79	0.337	8.56	0.295	7.49	1.125	28.58	0.984	24.99
0.133	3.38	0.116	2.95	0.344	8.74	0.301	7.64	1.156	29.36	1.012	25.70
0.140	3.56	0.122	3.10	0.358	9.09	0.313	7.95	1.219	30.96	1.066	27.08
0.141	3.58	0.123	3.12	0.365	9.27	0.319	8.10	1.250	31.75	1.094	27.79
0.145	3.68	0.127	3.23	0.375	9.52	0.328	8.33	1.281	32.54	1.121	28.47
0.147	3.73	0.129	3.28	0.382	9.70	0.334	8.48	1.312	33.32	1.148	29.16
0.154	3.91	0.135	3.43	0.400	10.16	0.350	8.89	1.375	34.92	1.203	30.56
0.156	3.96	0.136	3.45	0.406	10.31	0.355	9.02	1.406	35.71	1.230	31.24
0.172	4.37	0.150	3.81	0.432	10.97	0.378	9.60	1.438	36.53	1.258	31.95
0.179	4.55	0.157	3.99	0.436	11.07	0.382	9.70	1.500	38.10	1.312	33.32
0.188	4.78	0.164	4.17	0.438	11.12	0.383	9.73	1.531	38.89	1.340	34.04
0.191	4.85	0.167	4.24	0.469	11.91	0.410	10.41	1.562	39.67	1.367	34.72
0.200	5.08	0.175	4.44	0.500	12.70	0.438	11.13	1.594	40.49	1.395	35.43
0.203	5.16	0.178	4.52	0.531	13.49	0.465	11.81	1.635	41.53	1.431	36.35
0.210	5.33	0.184	4.67	0.552	14.02	0.483	12.27	1.750	44.45	1.531	38.89
0.216	5.49	0.189	4.80	0.562	14.27	0.492	12.50	1.781	45.24	1.558	39.57
0.218	5.54	0.191	4.85	0.594	15.09	0.520	13.21	1.812	46.02	1.586	40.28
0.219	5.56	0.192	4.88	0.600	15.24	0.525	13.34	1.875	47.62	1.641	41.68
0.226	5.74	0.198	5.03	0.625	15.88	0.547	13.89	1.969	50.01	1.723	43.76
0.237	6.02	0.207	5.26	0.656	16.66	0.574	14.58	2.000	50.80	1.750	44.45
0.250	6.35	0.219	5.56	0.674	17.12	0.590	14.99	2.062	52.37	1.804	45.82
0.258	6.55	0.226	5.74	0.688	17.48	0.602	15.29	2.125	53.98	1.859	47.22
0.276	7.01	0.242	6.15	0.719	18.26	0.629	15.98	2.200	55.88	1.925	48.90
0.277	7.04	0.242	6.15	0.750	19.05	0.656	16.66	2.344	59.54	2.051	52.10
0.279	7.09	0.244	6.19	0.812	20.62	0.710	18.03	2.500	63.50	2.188	55.58
0.280	7.11	0.245	6.22	0.844	21.44	0.739	18.77				

TABLE X1.2
DIMENSIONS, WEIGHTS AND TEST PRESSURES FOR PLAIN END PIPE
(As appears in American National Standard B36.10)

NPS Designator	Wall Thickness	Nominal Weight	Weight Class	Schedule No.	Test Pressure	
					Grade I	Grade II
	in. (mm)	lb/ft (kg/m)			psi (MPa)	psi (MPa)
1/8	0.068 (1.73)	0.24 (0.36)	std	40	2500 (17.2)	. . .
	0.095 (2.41)	0.31 (0.46)	XS	80	2500 (17.2)	. . .
1/4	0.088 (2.24)	0.42 (0.63)	std	40	2500 (17.2)	. . .
	0.119 (3.02)	0.54 (0.80)	XS	80	2500 (17.2)	. . .
3/8	0.091 (2.31)	0.57 (0.85)	std	40	2500 (17.2)	. . .
	0.126 (3.20)	0.74 (1.10)	XS	80	2500 (17.2)	. . .
1/2	0.109 (2.77)	0.85 (1.27)	std	40	2500 (17.2)	. . .
	0.147 (3.73)	1.09 (1.62)	XS	80	2500 (17.2)	. . .
	0.294 (7.47)	1.71 (2.55)	XXS	. . .	2500 (17.2)	. . .
3/4	0.113 (2.87)	1.13 (1.68)	std	40	2500 (17.2)	. . .
	0.154 (3.91)	1.47 (2.19)	XS	80	2500 (17.2)	. . .
	0.308 (7.82)	2.44 (3.63)	XXS	. . .	2500 (17.2)	. . .
1	0.133 (3.38)	1.68 (2.50)	std	40	2500 (17.2)	. . .
	0.179 (4.55)	2.17 (3.23)	XS	80	2500 (17.2)	. . .
	0.358 (9.09)	3.66 (5.45)	XXS	. . .	2500 (17.2)	. . .
1 1/4	0.140 (3.56)	2.27 (3.38)	std	40	2500 (17.2)	. . .
	0.191 (4.85)	3.00 (4.47)	XS	80	2500 (17.2)	. . .
	0.382 (9.70)	5.21 (7.76)	XXS	. . .	. . .	2500 (17.2)
1 1/2	0.145 (3.68)	2.72 (4.05)	std	40	2500 (17.2)	. . .
	0.200 (5.08)	3.63 (5.41)	XS	80	2500 (17.2)	. . .
	0.400 (10.16)	6.41 (9.55)	XXS	. . .	. . .	2500 (17.2)
2	0.154 (3.91)	3.65 (5.44)	std	40	2500 (17.2)	. . .
	0.218 (5.54)	5.02 (7.48)	XS	80	2500 (17.2)	. . .
	0.344 (8.74)	7.46 (11.12)	. . .	160	2500 (17.2)	. . .
	0.436 (11.07)	9.03 (13.45)	XXS	. . .	. . .	2500 (17.2)
2 1/2	0.203 (5.16)	5.79 (8.62)	std	40	2500 (17.2)	. . .
	0.276 (7.01)	7.66 (11.41)	XS	80	2500 (17.2)	. . .
	0.375 (9.52)	10.01 (14.91)	. . .	160	2500 (17.2)	. . .
	0.552 (14.02)	13.70 (20.41)	XXS	. . .	. . .	2500 (17.2)
3	0.216 (5.49)	7.58 (11.29)	std	40	2500 (17.2)	. . .
	0.300 (7.62)	10.25 (15.27)	XS	80	2500 (17.2)	. . .
	0.438 (11.13)	14.32 (21.34)	. . .	160	. . .	2500 (17.2)
	0.600 (15.24)	18.58 (27.67)	XXS	. . .	. . .	2500 (17.2)
3 1/2	0.226 (5.74)	9.11 (13.57)	std	40	2400 (16.5)	. . .
	0.318 (8.08)	12.51 (18.63)	XS	80	2800 (19.3)	. . .
4	0.237 (6.02)	10.79 (16.07)	std	40	2200 (15.2)	. . .
	0.337 (8.56)	14.98 (22.31)	XS	80	2800 (19.3)	. . .
	0.438 (11.13)	19.00 (28.30)	. . .	120	. . .	2800 (19.3)
	0.531 (13.49)	22.51 (33.53)	. . .	160	. . .	2800 (19.3)
	0.674 (17.12)	27.54 (41.02)	XXS	. . .	. . .	2800 (29.3)
5	0.258 (6.55)	14.62 (21.78)	std	40	1900 (13.1)	. . .
	0.375 (9.52)	20.78 (30.95)	XS	80	2800 (19.3)	. . .
	0.500 (12.70)	27.04 (40.28)	. . .	120	. . .	2800 (19.3)
	0.625 (15.88)	32.96 (49.09)	. . .	160	. . .	2800 (19.3)
	0.750 (19.05)	38.55 (57.42)	XXS	. . .	. . .	2800 (19.3)
6	0.280 (7.11)	18.97 (28.26)	std	40	1800 (12.4)	. . .
	0.432 (10.97)	28.57 (42.56)	XS	80	. . .	2300 (15.9)
	0.562 (14.27)	36.39 (54.20)	. . .	120	. . .	2800 (19.3)
	0.719 (18.26)	45.35 (67.55)	. . .	160	. . .	2800 (19.3)
	0.864 (21.95)	53.16 (79.68)	XXS	. . .	. . .	2800 (19.3)

TABLE X1.2 (CONT'D)
DIMENSIONS, WEIGHTS AND TEST PRESSURES FOR PLAIN END PIPE
(As appears in American National Standard B36.10)

NPS Designator	Wall Thickness in. (mm)	Nominal Weight lb/ft (kg/m)	Weight Class	Schedule No.	Test Pressure Grade I psi (MPa)	Test Pressure Grade II psi (MPa)
8	0.250 (6.35)	22.36 (33.31)	. . .	20	1200 (8.3)	. . .
	0.277 (7.04)	24.70 (36.79)	. . .	30	1300 (9.0)	. . .
	0.322 (8.18)	28.55 (42.53)	std	40	1600 (11.0)	. . .
	0.406 (10.31)	35.64 (53.10)	. . .	60	. . .	1700 (11.7)
	0.500 (12.70)	43.39 (64.63)	XS	80	. . .	2100 (14.5)
	0.594 (15.09)	50.95 (75.92)	. . .	100	. . .	2500 (17.2)
	0.719 (18.26)	60.71 (90.43)	. . .	120	. . .	2800 (19.3)
	0.812 (20.62)	67.76 (100.96)	. . .	140	. . .	2800 (19.3)
	0.875 (22.22)	72.42 (107.87)	XXS	. . .	. . .	2800 (19.3)
	0.906 (23.01)	74.69 (111.29)	. . .	160	. . .	2800 (19.3)
10	0.250 (6.35)	28.04 (41.77)	. . .	20	1000 (6.9)	. . .
	0.279 (7.09)	31.20 (46.47)	. . .	. . .	1100 (7.6)	. . .
	0.307 (7.80)	34.24 (51.00)	. . .	30	1200 (8.3)	. . .
	0.365 (9.27)	40.48 (60.29)	std	40	1400 (9.7)	. . .
	0.500 (12.70)	54.74 (81.55)	XS	60	. . .	1700 (11.7)
	0.594 (15.09)	64.43 (96.00)	. . .	80	. . .	2000 (13.8)
	0.719 (18.26)	77.03 (114.74)	. . .	100	. . .	2400 (16.5)
	0.844 (21.44)	89.29 (133.04)	. . .	120	. . .	2800 (9.3)
	1.000 (25.40)	104.13 (155.15)	XXS	140	. . .	2800 (9.3)
	1.125 (28.58)	115.65 (172.32)	. . .	160	. . .	2800 (9.3)
12	0.250 (6.35)	33.38 (49.72)	. . .	20	800 (5.5)	. . .
	0.330 (8.38)	43.77 (65.20)	. . .	30	1100 (7.6)	. . .
	0.375 (9.52)	49.56 (73.82)	std	. . .	1200 (8.3)	. . .
	0.406 (10.31)	53.52 (79.74)	. . .	40	. . .	1100 (7.6)
	0.500 (12.70)	65.42 (97.44)	XS	. . .	. . .	1400 (9.7)
	0.562 (14.27)	73.15 (108.96)	. . .	60	. . .	1600 (11.0)
	0.688 (17.48)	88.63 (132.01)	. . .	80	. . .	1900 (13.1)
	0.844 (21.44)	107.32 (159.91)	. . .	100	. . .	2400 (16.5)
	1.000 (25.40)	125.49 (186.98)	XXS	120	. . .	2800 (19.3)
	1.125 (28.58)	139.68 (208.12)	. . .	140	. . .	2800 (19.3)
	1.312 (33.32)	160.27 (238.80)	. . .	160	. . .	2800 (19.3)
14	0.250 (6.35)	36.71 (54.68)	. . .	10	750 (5.2)	. . .
	0.312 (7.92)	45.61 (67.94)	. . .	20	950 (6.6)	. . .
	0.375 (9.52)	54.57 (81.28)	std	30	1100 (7.6)	. . .
	0.438 (11.13)	63.44 (94.49)	. . .	40	. . .	1100 (7.6)
	0.500 (12.70)	72.09 (107.38)	XS	. . .	. . .	1300 (9.0)
	0.594 (15.09)	85.05 (126.72)	. . .	60	. . .	1500 (10.3)
	0.750 (19.05)	106.13 (158.08)	. . .	80	. . .	1900 (13.1)
	0.938 (23.83)	130.85 (194.90)	. . .	100	. . .	2400 (16.5)
	1.094 (27.79)	150.79 (234.68)	. . .	120	. . .	2800 (19.3)
	1.250 (31.75)	170.22 (253.63)	. . .	140	. . .	2800 (19.3)
	1.406 (35.71)	189.11 (281.77)	. . .	160	. . .	2800 (19.3)
16	0.250 (6.35)	42.05 (62.63)	. . .	10	650 (4.5)	. . .
	0.312 (7.92)	52.27 (77.86)	. . .	20	800 (5.5)	. . .
	0.375 (9.52)	62.58 (93.21)	std	30	1000 (6.9)	. . .
	0.500 (12.70)	82.77 (123.29)	XS	40	. . .	1100 (7.6)
	0.656 (16.66)	107.50 (160.18)	. . .	60	. . .	1500 (10.3)
	0.844 (21.44)	136.62 (203.56)	. . .	80	. . .	1900 (13.1)
	1.031 (26.19)	164.82 (245.58)	. . .	100	. . .	2300 (15.9)
	1.219 (30.96)	192.43 (286.72)	. . .	120	. . .	2700 (18.6)

TABLE X1.2 (CONT'D)
DIMENSIONS, WEIGHTS AND TEST PRESSURES FOR PLAIN END PIPE
(As appears in American National Standard B36.10)

NPS Designator	Wall Thickness in. (mm)	Nominal Weight lb/ft (kg/m)	Weight Class	Schedule No.	Test Pressure Grade I psi (MPa)	Test Pressure Grade II psi (MPa)
	1.438 (36.52)	223.64 (333.22)	. . .	140	. . .	2800 (19.3)
	1.594 (40.49)	245.25 (365.42)	. . .	160	. . .	2800 (19.3)
18	0.250 (6.35)	47.39 (70.59)	. . .	10	600 (4.1)	. . .
	0.312 (7.92)	58.94 (87.79)	. . .	20	750 (5.2)	. . .
	0.375 (9.52)	70.59 (105.14)	std	. . .	900 (6.2)	. . .
	0.438 (11.13)	82.15 (122.36)	. . .	30	. . .	900 (6.2)
	0.500 (12.70)	93.45 (139.19)	XS	. . .	. . .	1000 (6.9)
	0.562 (14.27)	104.67 (155.91)	. . .	40	. . .	1100 (7.6)
	0.750 (19.05)	138.17 (205.80)	. . .	60	. . .	1500 (10.3)
	0.938 (23.83)	170.92 (254.59)	. . .	80	. . .	1900 (13.1)
	1.156 (29.36)	207.96 (309.86)	. . .	100	. . .	2300 (15.9)
	1.375 (34.92)	244.14 (363.77)	. . .	120	. . .	2800 (19.3)
	1.562 (39.67)	274.22 (408.54)	. . .	140	. . .	2800 (19.3)
	1.781 (45.24)	308.50 (459.67)	. . .	160	. . .	2800 (19.3)
20	0.250 (6.35)	52.73 (78.54)	. . .	10	500 (3.4)	. . .
	0.375 (9.52)	78.60 (117.07)	std	20	800 (5.5)	. . .
	0.500 (12.70)	104.13 (155.10)	XS	30	. . .	900 (6.2)
	0.594 (15.09)	123.11 (183.43)	. . .	40	. . .	1100 (7.6)
	0.812 (20.62)	166.40 (247.85)	. . .	60	. . .	1500 (10.3)
	1.031 (26.19)	208.87 (311.22)	. . .	80	. . .	1900 (13.1)
	1.281 (32.54)	256.10 (381.59)	. . .	100	. . .	2300 (15.9)
	1.500 (38.10)	296.37 (441.59)	. . .	120	. . .	2700 (18.6)
	1.750 (44.45)	341.10 (508.24)	. . .	140	. . .	2800 (19.3)
	1.969 (50.01)	379.17 (564.96)	. . .	160	. . .	2800 (19.3)
24	0.250 (6.35)	63.41 (94.45)	. . .	10	450 (3.1)	. . .
	0.375 (9.52)	94.62 (140.94)	std	20	650 (4.5)	. . .
	0.500 (12.70)	125.49 (186.92)	XS	. . .	. . .	750 (5.2)
	0.562 (14.27)	140.68 (209.54)	. . .	30	. . .	850 (5.9)
	0.688 (17.48)	171.29 (255.14)	. . .	40	. . .	1000 (6.9)
	0.969 (24.61)	238.85 (355.89)	. . .	60	. . .	1500 (10.3)
	1.219 (30.96)	296.58 (441.90)	. . .	80	. . .	1800 (12.4)
	1.531 (38.89)	367.39 (547.41)	. . .	100	. . .	2300 (15.9)
	1.812 (46.02)	429.39 (639.79)	. . .	120	. . .	2700 (18.6)
	2.062 (52.37)	483.12 (719.25)	. . .	140	. . .	2800 (19.3)
	2.344 (59.64)	542.14 (807.79)	. . .	160	. . .	2800 (19.3)
26	0.250 (6.35)	68.75 (102.40)	. . .	. . .	400 (2.8)	. . .
	0.312 (7.92)	86.60 (127.50)	. . .	10	500 (3.4)	. . .
	0.375 (9.52)	102.63 (152.87)	std	. . .	610 (4.2)	. . .
	0.500 (12.70)	136.17 (202.83)	XS	20	. . .	690 (4.8)

SPECIFICATION FOR GENERAL REQUIREMENTS FOR SPECIALIZED CARBON AND ALLOY STEEL PIPE

SA-530/SA-530M

(Identical with ASTM Specification A 530/A 530M-96.) 98

1. Scope

1.1 This specification covers a group of requirements which, with the exceptions of Sections 4.3, 12, 19, and 20, are mandatory requirements to the ASTM pipe product specifications noted below unless the product specification specifies different requirements, in which case the requirement of the product specification shall prevail.

1.2 Sections 4.3 or 6 are mandatory if the product specification has a requirement for product analysis or flattening tests.

1.3 Section 20 is mandatory if the product specification has a hydrostatic test requirement without defining the test parameters.

98 **1.4** Section 12 is for information only.

1.5 In case of conflict between a requirement of the product specification and a requirement of this general requirement specification, only the requirement of the product specification need be satisfied.

Title of Specification	ASTM Designation[A]
Seamless Carbon Steel Pipe for High-Temperature Service	A 106
Seamless and Welded Austenitic Stainless Steel Pipe	A 312/A 312M
Seamless and Welded Steel Pipe for Low-Temperature Service	A 333/A 333M
Seamless Ferritic Alloy Steel Pipe for High-Temperature Service	A 335/A 335M
Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service	A 358/A 358M
Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service	A 369/A 369M
Seamless Austenitic Steel Pipe for Use With High-Temperature Central-Station Service	A 376/A 376M
Metal-Arc-Welded Steel Pipe for Use With High-Pressure Transmission Systems	A 381
Seamless Ferritic Alloy Steel Pipe Specially Heat Treated for High-Temperature Service	A 405
Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service	A 409/A 409M
Centrifugally Cast Ferritic Alloy Steel Pipe for High-Temperature Service	A 426
Austenitic Steel Forged and Bored Pipe for High-Temperature Service	A 430/A 430M
Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service	A 451
Centrifugally Cast Austenitic Steel Cold-Wrought Pipe for High-Temperature Service	A 452
Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures	A 524
Centrifugally Cast Iron-Chromium-Nickel High-Alloy Tubing for Pressure Application at High Temperatures	A 608
Centrifugally Cast Carbon Steel Pipe for High-Temperature Service	A 660
Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures	A 671
Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures	A 672
Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures	A 691
Seamless, Welded Ferritic, and Martensitic Stainless Steel Pipe	A 731/A 731M

Title of Specification	ASTM Designation[A]
Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe	A 790/A 790M
Single- or Double-Welded Austenitic Stainless Steel Pipe	A 813/A 813M
Cold-Worked Welded Austenitic Stainless Steel Pipe	A 814/A 814M
Centrifugally Cast Ferritic/Austenitic Stainless Steel Pipe for Corrosive Environments	A 872

[A] These designations refer to the latest issue of the respective specifications.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation (SI) of the product specification is specified in the order.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Steel Tubes

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

D 3951 Practice for Commercial Packaging

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specification

2.2 *ANSI Standards:*

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *Military Standards:*

MIL-STD-271 Nondestructive Testing Requirements for Metals

MIL-STD-792 Identification Marking Requirements for Special Purpose Equipment

2.4 *Federal Standards:*

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.5 *Steel Structures Painting Council:*

SSPC-SP6 Surface Preparation Specification No. 6 Commercial Blast Cleaning

3. Process

3.1 The steel shall be made from any process.

3.2 If a specific type of melting is required by the purchaser, it shall be stated on the purchase order.

3.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, using electroslag remelting or vacuum remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

3.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

4. Chemical Composition

4.1 *Chemical Analysis* — Samples for chemical analysis and method of analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

4.2 *Heat Analysis* — An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer shall conform to the requirements specified.

4.2.1 For stainless steels ordered under product specifications referencing this specification of general requirements, the steel shall not contain an unspecified element, other than nitrogen, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation in a table of chemical requirements within any specification listed within the scope as being covered by this specification. **98**

4.3 *Product Analysis* — Product analysis requirements and options, if any, are contained in the product specification.

5. Mechanical Requirements

5.1 *Method of Mechanical Tests* — The specimens and the mechanical tests required shall be in accordance with Test Methods and Definitions A 370, especially Annex A2 thereof.

5.2 Specimens shall be tested at room temperature.

5.3 Small or subsize specimens as described in Test Methods and Definitions A 370 may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

6. Tensile Requirements

6.1 The material shall conform to the requirements as to tensile properties prescribed in the individual specifications.

6.2 The yield strength corresponding to a permanent offset of 0.2% of the gage length or to a total extension of 0.5% of the gage length under load shall be determined.

6.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. [19.0 mm] from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

7. Permissible Variation in Weight for Seamless Pipe

7.1 The weight of any length of seamless pipe NPS 12 and under shall not vary more than 10% over and 3.5% under that specified. For sizes over NPS 12, the weight of any length of pipe shall not vary more than 10% over and 5% under that specified. Unless otherwise specified, pipe of NPS 4 and smaller may be weighed in convenient lots; pipe in sizes larger than NPS 4 shall be weighed separately.

8. Permissible Variations in Wall Thickness

8.1 *Seamless and Welded (no filler metal added)* — The minimum wall thickness at any point shall not be more than 12.5% under the nominal wall thickness specified. The minimum wall thickness on inspection is shown in Table X1.1.

8.2 *Forged and Bored* — The wall thickness shall not vary over that specified by more than $\frac{1}{8}$ in. [3.2 mm]. There shall be no variation under the specified wall thickness.

8.3 *Cast* — The wall thickness shall not vary over that specified by more than $^{1}/_{16}$ in. [1.6 mm]. There shall be no variation under the specified wall thickness.

9. Permissible Variations in Inside Diameter

9.1 *Forged and Bored, and Cast* — The inside diameter shall not vary under that specified by more than $^{1}/_{16}$ in. [1.6 mm]. There shall be no variation over the specified inside diameter.

10. Permissible Variations in Outside Diameter

10.1 Variations in outside diameter, unless otherwise specified, shall not exceed the limits prescribed in Table 1. The tolerances on outside diameter include ovality except as provided for in 10.2 and 10.2.1.

10.2 Thin-wall pipe usually develops significant ovality (out-of-roundness) during final annealing, straightening, or both. Thin-wall pipes are defined as having a wall thickness of 3% or less of the outside diameter.

10.2.1 The diameter tolerances of Table 1 are not sufficient to provide for additional ovality expected in thin-wall pipe and are applicable only to the mean of the extreme (maximum and minimum) outside diameter readings in any one cross-section. However, for thin-wall pipe the difference in extreme outside diameter readings (ovality) in any one cross-section shall not exceed 1.5% of the specified outside diameter.

11. Permissible Variations in Length

11.1 *Seamless and Welded (no filler metal added)* — If definite cut lengths are ordered, no length of pipe shall be under the length specified and not more than $\frac{1}{4}$ in. [6 mm] over that specified.

11.2 *Forged and Bored, Cast, and Cast Cold-Wrought* — If definite cut lengths are ordered, no length of pipe shall be under the length specified and not more than $\frac{1}{8}$ in. [3 mm] over that specified.

11.3 For pipe ordered to random lengths, the lengths and variations shall be agreed upon between the manufacturer and purchaser.

11.4 No jointers are permitted unless otherwise agreed upon.

12. Standard Weight

12.1 A system of standard pipe sizes has been approved by the American National Standards Institute as ANSI B36.10 and B36.19. These standard sizes do not prohibit the production and use of other sizes of pipe produced to the various specifications referenced to this Specification.

98 **12.2** For nonstandard sizes of pipe, the calculated weight per foot, shall be determined from the following equation:

$$W = C(D - t)t \quad (1)$$

where:

C = 10.69 [0.0246615],
W = weight, lb/ft [kg/m],
D = specified or calculated (from specified inside diameter and wall thickness) outside diameter, in. [mm], and
t = specified wall thickness, in. (to 3 decimal places) [mm to 2 decimal places].

NOTE 2—The weights given in the American National Standards and the calculated weights given by Eq. (1) are based on the weights for carbon steel pipe. The weight of pipe made of ferritic stainless steels may be about 5% less, and that made of austenitic stainless steel about 2% greater than the values given.

13. Ends

13.1 Unless otherwise specified, the pipe shall be furnished with plain ends. All burrs at the ends of the pipe shall be removed.

14. Straightness

14.1 The finished pipe shall be reasonably straight.

14.2 For metal-arc welded pipe, the maximum deviation from a 10 ft [3.0 m] straightedge placed so that both ends are in contact with the pipe shall be $\frac{1}{8}$ in. [3.2 mm]. For metal-arc welded pipe with lengths shorter than 10 ft [3.0 m], this maximum deviation shall be pro-rated with respect to the ratio of the actual length to 10 ft [3.0 m].

15. Repair by Welding

15.1 Repair by welding of defects in seamless pipe (including centrifugally cast and forged and bored) and of plate defects in welded pipe and, when specifically stated by the product specification weld seam defects in welded pipe, shall be permitted subject to the approval of the purchaser and with the further understanding that the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable specification. Each length of repaired pipe shall be tested hydrostatically as required by the product specification.

15.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

16. Retests

16.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional lengths of pipe of double the original number from the same group or lot, each of which shall conform to the requirements specified. Only one retest of any group or lot will be permitted. Nonconformance will be cause for the rejection of the group or lot.

16.2 Any individual length of pipe that meets the test requirements is acceptable. Individual lengths that do not conform to the test requirements may be resubmitted for test provided the reason for nonconformance is established and the nonconforming portion removed.

17. Retreatment

17.1 If individual lengths of pipe selected to represent any group or lot fail to conform to the test requirements, the group or lot represented may be reheat treated and resubmitted for test. The manufacturer may reheat treat the pipe, but not more than twice, except with the approval of the purchaser on the basis of satisfactory metallurgical evidence that the cause of failure of the test is curable and the quality of the material is satisfactory.

18. Test Specimens

18.1 Test specimens shall be taken from the ends of finished pipe prior to any forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws, except for specimens for the flattening test when made from crop ends.

18.2 Specimens cut either longitudinally or transversely shall be acceptable for the tension test.

18.3 If any test specimen shows flaws or defective machining, the specimen may be discarded and another substituted.

19. Flattening Test Requirements

19.1 *Seamless and Centrifugally Cast Pipe* — A section of pipe not less than 2½ in. [63 mm] in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside, outside, or end surfaces, except as provided for in 19.3.4, shall occur until the distance between the plates is less than the value of H calculated as follows:

$$H = (1 + e)t/(e + t/D) \quad (2)$$

where:

H = distance between flattening plates, in. [mm],
t = specified wall thickness, in. [mm],
D = specified or calculated (from the specified inside diameter and wall thickness) outside diameter, in. [mm], and
e = deformation per unit length (constant for a given grade of steel; 0.07 for medium carbon steel (maximum specified carbon 0.19% or greater), 0.08 for ferritic alloy steel, 0.09 for austenitic steel, and 0.09 for low-carbon steel (maximum specified carbon 0.18 or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet.

19.2 *Welded Pipe* — A section of welded pipe not less than 4 in. [100 mm] in length shall be flattened cold between parallel plates in two steps. The weld shall be placed 90° from the direction of the applied force (at the point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks on the inside or outside surfaces, except as provided for in 19.3.4, shall occur until the distance between the plates is less than the value of H calculated by the Eq. (2). During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet.

19.3 *Seamless, Centrifugally Cast, and Welded Pipe:*

19.3.1 Evidence of laminated or defective material or weld that is revealed during the entire flattening test shall be cause for rejection.

19.3.2 Surface imperfections not evident in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

19.3.3 Superficial ruptures resulting from surface imperfections shall not be a cause for rejection.

19.3.4 When low D-to-t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D to t ratio is less than 10.

20. Hydrostatic Test Requirements

20.1 Except as provided in 20.2 and 20.3, each length of pipe shall be tested by the manufacturer to a hydrostatic pressure which will produce in the pipe wall a stress not less that 60% of the minimum specified yield strength for carbon and ferritic alloy steel pipe, or 50% of the specified minimum yield strength for austenitic alloy steel pipe. The test pressure or stress shall be determined by the following equation:

$$P = 2St/D \quad \text{or} \quad S = PD/2t \quad (3)$$

where:

P = hydrostatic test pressure in psi or MPa,
S = pipe wall stress in psi or MPa
t = specified nominal wall thickness, nominal wall thickness corresponding to specified ANSI schedule number, or 1.143 times the specified minimum wall thickness, in. [mm], and
D = specified outside diameter, outside diameter corresponding to specified ANSI pipe size, or outside diameter calculated by adding $2t$ (as defined above) to the specified inside diameter, in. [mm].

20.1.1 The hydrostatic test pressure determined by the equation shall be rounded to the nearest 50 psi [0.5 MPa] for pressures below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi

[7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending, or other forming operations.

20.2 Regardless of pipe-wall stress-level determined by Eq. (3), the minimum hydrostatic test pressure required to satisfy these requirements need not exceed 2500 psi [17.0 MPa] for outside diameters (see *D* in 20.1) of 3.5 in. [88.9 mm] or less, nor 2800 psi [19.0 MPa] for outside diameters over 3.5 in. [88.9 mm]. This does not prohibit testing at higher pressures at the manufacturer's option or as provided in 20.3.

20.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 20.2 or 20.1, or both, may be stated on the order.

98 **20.4** The test pressure shall be held for a minimum of 5 s without resultant leakage through the pipe wall. For welded pipe, the test pressure shall be held for a time sufficient to permit the inspector to examine the entire length of the welded seam.

20.5 The hydrostatic test may not be capable of inspecting the end portion of the pipe. The length of pipe that cannot be tested shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

21. Inspection

21.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with operation of the works.

22. Rejection

22.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

22.2 Pipe that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the suitability of the pipe. Disposition of such pipe shall be a matter for agreement.

23. Certified Test Report

23.1 When Specified in the purchase order or contract the producer or supplier shall furnish a Certified Test Report certifying that the material was manufactured, sampled, tested, and inspected in accordance with the Specification, including year date, the Supplementary Requirements, and any other requirements designated in the purchase order or contract, and that the results met the requirements of that Specification, the Supplementary Requirements, and the other requirements. A signature or notarization is not required on the Certified Test Report, but the document shall be dated and shall clearly identify the organization submitting the Report.

NOTE 3—Notwithstanding the absence of a signature or notarization, the organization submitting the Report is responsible for the contents of the Report.

23.2 In addition, the Certified Test Report shall include the following information and test results, when applicable:

23.2.1 Heat Number,

23.2.2 Heat Analysis,

23.2.3 Product Analysis, if specfied or required,

23.2.4 Tensile Properties,

23.2.5 Width of the gage length, when longitudinal strip tension test specimens are used,

23.2.6 Bend Test acceptable,

23.2.7 Flattening Test acceptable,

23.2.8 Hydrostatic Test pressure,

23.2.9 Non-destructive Electric Test method,

23.2.10 Impact Test results, and

23.2.11 Other test results or information required to be reported by the product specification.

23.3 Test results or information required to be reported by supplementary requirements, or other require-

ments designated in the purchase order or contract shall be reported, but may be reported in a separate document.

23.4 The Certified Test Report shall include a statement of explanation for the letter added to the specification number marked on the tubes (see 24.5) when all of the requirements of the specification have not been completed. The purchaser must certify that all requirements of the specification have been completed before removal of the letter (that is, X, Y, or Z).

23.5 When certification is required for material that has not been hydrostatically tested, the Certificate of Test shall state "Not hydrostatically tested," and the letters "NH" shall be appended to the product specification number, material grade, and class shown on the Certificate.

24. Product Marking

24.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the specification number (year of issue not required), and grade. Marking shall begin approximately 12 in. [300 mm] from the end of each length of pipe. For pipe less than NPS 2 and pipe under 3 ft [1 m] in length, the required information may be marked on a tag securely attached to the bundle or box in which the pipes are shipped.

24.2 When pipe marked as specified is rejected, the ASTM designation shall be cancelled.

24.3 For austenitic steel pipe, the marking paint or ink shall not contain any harmful metal, or metal salts, such as zinc, lead, or copper, which cause corrosive attack on heating.

24.4 Pipes which have been weld repaired in accordance with 15.1 shall be marked *WR*.

24.5 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicate that all requirements of the specification have not been completed by a letter such as *X*, *Y*, or *Z*, immediately following the specification number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in 23.1.

98 **24.6** *Bar Coding* — In addition to the requirements in 24.1, 24.2, 24.3, and 24.5, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group [AIAG] standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

25. Packaging, Marking, and Loading

25.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with the procedures of Practices A 700.

26. Government Procurement 98

26.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order for agencies of the U.S. Government where scale free pipe is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

26.1.1 Pipe shall be ordered to nominal pipe size (NPS) and schedule. Nominal pipe shall be as specified in ANSI B36.10.

26.1.2 *Responsibility for Inspection* — Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept the material. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

26.1.3 *Sampling for Flattening and Flaring Test and for Visual and Dimensional Examination* — Minimum sampling for flattening and flaring tests and visual and dimensional examination shall be as follows:

Lot Size (pieces per lot)	Sample Size
2 to 8	Entire lot
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 10 000	38
10 001 to 35 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots may be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance.

26.1.4 *Sampling for Chemical Analysis* — One sample for chemical analysis shall be selected from each of two pipes chosen from each lot. A lot shall be all material poured from one heat.

26.1.5 *Sampling for Tension and Bend Test* — One sample shall be taken from each lot. A lot shall consist of all pipe of the same outside diameter and wall thickness manufactured during an 8-h shift from the same heat of steel, and heat treated under the same conditions of temperature and time in a single charge in a batch type furnance, or heat treated under the same condition in a continuous furnace, and presented for inspection at the same time.

26.1.6 *Hydrostatic and Ultrasonic Tests* — Each pipe shall be tested by the ultrasonic (when specified) and hydrostatic tests.

26.1.7 Pipe shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel pipe shall be pickled or blast cleaned to a free of scale condition equivalent to the CSa2 visual standard listed in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

26.1.8 In additon to the marking in Specification A 450/A 450M, each length of pipe ¼ in. outside diameter and larger shall be marked with the following listed information. Marking shall be in accordance with FED-STD-183 and MIL-STD-792. (*a*) Nominal Pipe Size Schedule and Length (*b*) Heat or lot identification number.

26.1.9 Pipe shall be straight to within the tolerances specified in Table 2.

26.1.10 When specified, each pipe shall be ultrasonically examined in accordance with MIL-STD-271, except that the notch depth in the calibration standard shall be 5% of the wall thickness or 0.005 in., whichever is greater. Any pipe which produces an indication equal to or greater than 100% of the indication from the calibration standard shall be rejected.

26.1.11 The pipe shall be free from repair welds, welded joints, laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the pipe as determined by visual and ultrasonic examination, or alternate tests, as specified.

26.1.12 Pipe shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality pipe. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered injurious if the imperfections are removable within the tolerances specified for wall thickness or 0.005 in., whichever is greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.

26.1.13 No weld repair by the manufacturer is permitted.

26.1.14 Preservation shall be level A or commercial, and packing shall be level A, B, or commercial, as specified. Level A preservation and level A or B packing shall be in accordance with MIL-STD-163, and commercial preservation and packing shall be in accordance with Practices A 700 or Practice D 3951.

27. Keywords

98

27.1 alloy steel pipe; carbon steel pipe; general delivery requirements; steel pipe

TABLE 1
PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETER

NPS Designator	Permissible Variations in Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
1/8 to 1 1/2, incl	1/64 (0.015)	0.4	1/32 (0.031)	0.8
Over 1 1/2 to 4, incl	1/32 (0.031)	0.8	1/32 (0.031)	0.8
Over 4 to 8, incl	1/16 (0.062)	1.6	1/32 (0.031)	0.8
Over 8 to 18, incl	3/32 (0.093)	2.4	1/32 (0.031)	0.8
Over 18 to 26, incl	1/8 (0.125)	3.2	1/32 (0.031)	0.8
Over 26 to 34, incl	5/32 (0.156)	4.0	1/32 (0.031)	0.8
Over 34 to 48, incl	3/16 (0.187)	4.8	1/32 (0.031)	0.8

TABLE 2
STRAIGHTNESS TOLERANCES

Specified OD, in.	Specified wall thickness, in.	Maximum curvature in any 3 ft, in.	Maximum curvature in total length, in.
Up to 5.0, incl.	Over 3% OD to 0.5, incl.	0.030	0.010 × length, ft
Over 5.0 to 8.0, incl.	Over 4% OD to 0.75, incl.	0.045	0.015 × length, ft
Over 8.0 to 12.75, incl.	Over 4% OD to 1.0, incl.	0.060	0.020 × length, ft

APPENDIX

(Nonmandatory Information)

TABLE X1.1
TABLE OF MINIMUM WALL THICKNESSES ON INSPECTION FOR NOMINAL (AVERAGE) PIPE WALL THICKNESSES

NOTE 1 — The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:
t_n = nominal (average) wall thickness, in. [mm], and
t_m = minimum wall thickness, in. [mm].

The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped, in accordance with the Practice E 29.

NOTE 2 — This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)	
in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.068	1.73	0.060	1.52	0.294	7.47	0.257	6.53	0.750	19.05	0.656	16.62
0.088	2.24	0.077	1.96	0.300	7.62	0.262	6.65	0.812	20.62	0.710	18.03
0.091	2.31	0.080	2.03	0.307	7.80	0.269	6.83	0.843	21.41	0.738	18.75
0.095	2.41	0.083	2.11	0.308	7.82	0.270	6.86	0.864	21.95	0.756	19.20
0.113	2.87	0.099	2.51	0.312	7.92	0.273	6.93	0.875	22.22	0.766	19.46
0.119	3.02	0.104	2.64	0.318	8.08	0.278	7.06	0.906	23.01	0.793	20.14
0.125	3.18	0.109	2.77	0.322	8.18	0.282	7.17	0.937	23.80	0.820	20.83
0.126	3.20	0.110	2.79	0.330	8.38	0.289	7.34	0.968	24.59	0.847	21.51
0.133	3.38	0.116	2.95	0.337	8.56	0.295	7.49	1.000	25.40	0.875	22.22
0.140	3.56	0.122	3.10	0.343	8.71	0.300	7.62	1.031	26.19	0.902	22.91
0.145	3.68	0.127	3.23	0.344	8.74	0.301	7.65	1.062	26.97	0.929	23.60
0.147	3.73	0.129	3.28	0.358	9.09	0.313	7.95	1.093	27.76	0.956	24.28
0.154	3.91	0.135	3.43	0.365	9.27	0.319	8.10	1.125	28.57	0.984	24.99
0.156	3.96	0.136	3.45	0.375	9.52	0.328	8.33	1.156	29.36	1.012	25.70
0.179	4.55	0.157	3.99	0.382	9.70	0.334	8.48	1.218	30.94	1.066	27.08
0.187	4.75	0.164	4.17	0.400	10.16	0.350	8.89	1.250	31.75	1.094	27.77
0.188	4.78	0.164	4.17	0.406	10.31	0.355	9.02	1.281	32.54	1.121	28.47
0.191	4.85	0.167	4.24	0.432	10.97	0.378	9.60	1.312	33.32	1.148	29.16
0.200	5.08	0.175	4.44	0.436	11.07	0.382	9.70	1.343	34.11	1.175	29.84
0.203	5.16	0.178	4.52	0.437	11.10	0.382	9.70	1.375	34.92	1.203	30.56
0.216	5.49	0.189	4.80	0.438	11.13	0.383	9.73	1.406	35.71	1.230	31.24
0.218	5.54	0.191	4.85	0.500	12.70	0.438	11.13	1.438	36.52	1.258	31.95
0.219	5.56	0.192	4.88	0.531	13.49	0.465	11.81	1.500	38.10	1.312	33.32
0.226	5.74	0.198	5.03	0.552	14.02	0.483	12.27	1.531	38.89	1.340	34.04
0.237	6.03	0.207	5.23	0.562	14.27	0.492	12.50	1.562	39.67	1.367	34.72
0.250	6.35	0.219	5.56	0.593	15.06	0.519	13.18	1.593	40.46	1.394	35.40
0.258	6.55	0.226	5.74	0.600	15.24	0.525	13.34	1.750	44.45	1.531	38.89
0.276	7.01	0.242	6.15	0.625	15.88	0.547	13.89	1.781	45.24	1.558	39.57
0.277	7.04	0.242	6.15	0.656	16.62	0.573	14.55	1.812	46.02	1.586	40.28
0.279	7.09	0.244	6.20	0.674	17.12	0.590	14.99	1.968	49.99	1.772	43.74
0.280	7.11	0.245	6.22	0.687	17.45	0.601	15.27	2.062	52.38	1.804	45.82
0.281	7.14	0.246	6.25	0.719	18.26	0.629	15.98	2.343	59.51	2.050	52.07

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, QUENCHED AND TEMPERED, MANGANESE-MOLYBDENUM AND MANGANESE-MOLYBDENUM-NICKEL

SA-533/SA-533M

(Identical with ASTM Specification A 533/A 533M-93.)

1. Scope

1.1 This specification covers manganese-molybdenum and manganese-molybdenum-nickel alloy steel plates for use in the quenched and tempered condition for the construction of welded pressure vessels.

1.2 This specification includes four types of chemical analysis and three classes of strength levels as follows:

Type	Nominal Molybdenum Content, %	Nominal Nickel Content, %
A	0.50	. . .
B	0.50	0.55
C	0.50	0.85
D	0.50	0.30

Class	Tensile Strength, ksi [MPa]
1	80-100 [550 to 690]
2	90-115 [620 to 795]
3	100-125 [690 to 860]

1.3 The maximum thickness of Class 1 and Class 2 plates is limited only by the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness to 12 in. [300 mm].

1.4 The maximum thickness of Class 3 plates is $2\frac{1}{2}$ in. [65 mm].

1.5 The minimum nominal thickness of plates of all classes is 0.25 in. [6.5 mm].

1.6 These alloy steel plates in the as-rolled condition are sensitive to cracking during transit and handling, particularly in thicknesses over about 1 or 2 in. [25 or 50 mm]. They should be shipped in the as-rolled conditions only with the mutual agreement of manufacturer and fabricator.

1.7 Plates covered by this specification are often used in the beltline region of nuclear reactor vessels where the material properties may be affected by high levels of radiation. Appendix X1 provides some information pertinent to this usage.

1.8 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates
A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information which should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine austenitic grain requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be heat treated by heating to a suitable temperature within the range from 1550 to 1800°F [845 to 980°C], holding for a sufficient time to obtain uniform temperature throughout the plate thickness and then quenching, in water. Subsequently the plates shall be tempered at a suitable temperature to produce the specified properties, but not less than 1100°F [595°C] with a minimum holding time of ½ h/in. [1.2 min/mm] of thickness, but not less than ½ h.

5.2 When the plates are heat treated by the fabricator, it shall be his responsibility to apply the proper heat treatment and to conduct tests he deems necessary to assure that the specified properties are attained.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxided Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements:*

7.1.1 The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.1.2 For nominal plate thicknesses of ¾ in. [20 mm] and under, the 1½ in. [40 mm] wide rectangular specimen may be used, and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation.

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %			
	Type A	Type B	Type C	Type D
Carbon, max[A]	0.25	0.25	0.25	0.25
Manganese[B]:				
Heat analysis	1.15–1.50	1.15–1.50	1.15–1.50	1.15–1.50
Product analysis	1.07–1.62	1.07–1.62	1.07–1.62	1.07–1.62
Phosphorus, max[A]	0.035	0.035	0.035	0.035
Sulfur, max[A]	0.035	0.035	0.035	0.035
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45
Molybdenum:				
Heat analysis	0.45–0.60	0.45–0.60	0.45–0.60	0.45–0.60
Product analysis	0.41–0.64	0.41–0.64	0.41–0.64	0.41–0.64
Nickel:				
Heat analysis	. . .	0.40–0.70	0.70–1.00	0.20–0.40
Product analysis	. . .	0.37–0.73	0.67–1.03	0.17–0.43

[A] Applies to both heat and product analyses.
[B] The maximum manganese content may be increased to 1.60% on heat analysis and 1.65% on product analysis when Class 2 or Class 3 properties are specified and when Supplementary Requirement S3 (see Specification A 20/A 20M) is specified with a total holding time of more than 1 h/in. [2.4 min/mm] of thickness.

TABLE 2
TENSILE REQUIREMENTS

	Class 1	Class 2	Class 3
	ksi [MPa]	ksi [MPa]	ksi [MPa]
Tensile strength	80–100 [550–690]	90–115 [620–795]	100–125 [690–860]
Yield strength, min	50 [345]	70 [485]	83 [570]
Elongation in 2 in. [50 mm], min, %	18	16	16

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.2 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

S19. Restricted Chemical Requirements

APPENDIX

X1. NUCLEAR REACTOR BELTLINE CONSIDERATIONS — RESIDUAL ELEMENTS

X1.1 Reactor design requires review and control of residual elements that affect the material properties. Copper and phosphorus are limited to levels determined by the total fluence to be encountered during plant life. Vanadium and sulfur can affect the upper energy shelf level. In the case of sulfur, control of this element or its morphology in the plate, or both, may offer alternative means of control. The limits required shall be specified in the ordering data. The following table itemizes currently available commercial limits for the referenced elements:

Element	Heat Analysis, %	Product Analysis, %
Copper	0.10	0.12
Phosphorus	0.012	0.015
Sulfur	0.015	0.018
Vanadium	0.05	0.06

SPECIFICATION FOR ALLOY-STEEL BOLTING MATERIALS FOR SPECIAL APPLICATIONS

SA-540/SA-540M

(Identical with ASTM Specification A 540/A 540M-93.) 98

1. Scope

1.1 This specification covers regular and special-quality alloy steel bolting materials which may be used for nuclear and other special applications. Bolting materials as used in this specification cover rolled or forged bars, rotary pierced or extruded seamless tubes, bored bars, or forged hollows from forged or rolled bar segments to be manufactured into bolts, studs, washers, and nuts.

1.2 Several grades of steel are covered. The grade and class shall be specified by the purchaser.

1.3 Supplementary requirements of an optional nature are provided for use when special quality is desired. These supplementary requirements call for additional tests to be made and when desired shall be so stated in the order, together with the acceptance limits required.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron

E 45 Practice for Determining the Inclusion Content of Steel

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

2.2 *AIAG Standard:* 98

AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

3. Ordering Information

3.1 Orders for material under this specification shall include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet or number of lengths),

3.1.2 Size (diameter and length),

3.1.3 Specification designation,

3.1.4 Grade (Table 1),

3.1.5 Condition (Section 4),

3.1.6 Heat treatment (Section 5),

3.1.7 Class (Section 8),

3.1.8 Supplementary Requirements (S1 to S9),

3.1.9 Reports required (Section 19),

3.1.10 End use, and

3.1.11 Any special requirements.

4. Manufacture

4.1 The steel shall be produced by any of the following primary processes: open-hearth, basic-oxygen, electric-furnace, or vacuum-induction melting (VIM). The primary melting may incorporate separate degassing or refining. The molten steel may be vacuum-treated prior to or during pouring of the ingot. Secondary processes are also permitted whereby steels made from these primary processes are remelted using electroslag-remelting, or vacuum-arc remelting processes. The basic oxygen process shall be limited to steels containing not over 6% chromium.

4.2 The material shall be supplied hot-rolled or hot-forged or cold-finished at the option of the producer. However, if desired by the purchaser, cold finishing may be specified.

5. Heat Treatment

5.1 Material which is ordered in the annealed condition shall have a structure suitable for machining. Such annealed bolting material is not intended to be used without subsequent quenching and tempering as specified in 5.2.

5.2 Material which is ordered in the liquid-quenched and tempered condition shall be uniformly reheated from a temperature below the cooling transformation range to the proper austenitizing temperature. It shall be quenched in a liquid medium under substantially uniform conditions and then uniformly reheated for tempering. The minimum tempering temperature shall be 850°F [455°C].

5.3 Material that has been straightened after quenching and tempering shall be stress relieved by reheating to a temperature not lower than 100°F [55°C] under the tempering temperature.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements prescribed in Table 1. For referee purposes, Test Methods E 30 shall be used.

6.2 *Air-Melt Material* — An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of specified elements. The chemical analysis thus determined shall conform to the requirements prescribed in Table 1.

6.3 *Consumable-Remelted Material* — An analysis shall be made by the manufacturer on one remelted ingot (or the product of one remelted ingot) per heat and the results shall conform to the requirements prescribed in Table 1. A heat is defined as all of the ingots remelted from a single primary melt.

7. Product Analysis

7.1 Product analysis, if made, shall conform to the chemical requirements prescribed in Table 1. Samples for chemical analysis, except for spectrochemical analysis, shall be taken in accordance with Practice E 59.

8. Tensile Requirements

8.1 Material furnished in the annealed condition shall be capable of meeting the specified tensile properties for the class as specified in Table 2 when heat treated in accordance with 5.2 and 5.3 (see Supplementary Requirement S4).

8.2 Material in the quenched and tempered or quenched, tempered and stress-relieved condition shall conform to properties shown in Table 2 for the specified class.

9. Hardness Requirements

9.1 The hardness shall be determined on the surface of the material after removal of decarburization.

9.2 The hardness of material in the annealed condition shall not be greater than 235 HB.

9.3 The hardness of material in the quenched and tempered or quenched, tempered and stress-relieved condition shall be within the limits in Table 2 for the specified class.

10. Impact Requirements

10.1 Annealed material after proper heat treatment shall be capable of meeting the impact requirements in Table 2 or of Supplementary Requirement S8, if so specified (see Supplementary Requirement S4).

10.2 Material in the quenched and tempered or quenched, tempered, and stress-relieved condition shall conform to the impact requirements in Table 2, or of Supplementary Requirement S8 if so specified.

10.3 The percent of shear (ductility or fibrous) fracture shall be computed in accordance with the procedure described in Determination of Percent Shear Fracture in Test Methods and Definitions A 370. The computed value shall be recorded for all impact specimens.

10.4 The amount of lateral expansion shall be measured in accordance with the procedure described in the section on Determination of Lateral Expansion in Test Methods and Definitions A 370. The measured value shall be recorded for all impact specimens.

10.5 The percent shear and the amount of lateral expansion shall be reported for information purposes (see 19.1).

11. Dimensions and Tolerances

11.1 Permissible variations for bar dimensions shall be as prescribed in Table 3.

11.2 *Permissible Tolerances for Straightness:*

11.2.1 Annealed material shall have an out-of-straightness tolerance of $\frac{1}{8}$ in. [3 mm] in any 5 ft [2.1 mm/m] or

$$\frac{1}{8} \times \text{(number of feet of length/5) inches.}$$

11.2.2 Quenched, tempered and stress-relieved material shall have an out-of-straightness tolerance of $\frac{1}{4}$ in. [6 mm] in any 5 ft [4.2 mm/m] or

$$\frac{1}{4} \times \text{(number of feet of length/5) inches.}$$

12. Workmanship, Finish, and Appearance

12.1 The material shall be uniform in quality and free of defects that would be detrimental to the intended service. If magnetic particle inspection for such defects is desired, Supplementary Requirement S6 should be specified.

12.2 *Surface Quality* — Material shall be free of seams, laps, cracks, or other defects that are not removable within the machining cleanup allowance specified in Table 4.

13. Surface Condition

13.1 Material shall be cleaned and furnished in the scale-free condition.

14. Number of Tests

14.1 *Mechanical Tests on Quenched and Tempered Material:*

14.1.1 One test coupon shall be removed from each end of one bar, one seamless tube, or one bored bar or from each of two forged hollows from each size of each heat in each tempering charge, or each 10 000 lb [4540 kg], whichever is less. One tension test and one impact test consisting of three Charpy V-notch specimens shall be taken from each test coupon. For testing in accordance with 16.2.1, two tests shall be obtained from two representative production pieces from each size of each heat in each tempering charge or each 10 000 lb [4540 kg], whichever is less.

14.1.2 *Hardness Test:*

14.1.2.1 Bars 2 in. [50 mm] and over and all seamless tubes or bored bars shall be tested near each end of each mill-treated length. Each forged hollow with thickness 2 in. [50 mm] or over shall be tested on the surface.

14.1.2.2 Bars under 2 in. [50 mm] shall be tested near each end of not less than 10% of the bars. Forged hollows less than 2 in. [50 mm] thick shall be tested on the surface of not less than 10% of the forgings.

14.2 *Hardness Tests of Annealed Material:*

14.2.1 Hardness tests shall be made on the annealed bars to assure compliance with 10.2.

15. Retests

15.1 If the results of the mechanical tests of any test lot do not conform to the specified requirements, the manufacturer shall reject the lot or he may retreat such a lot not more than twice. After the lot is retreated, all of the tests specified in Section 14 shall be repeated, and all shall conform to the specified requirements.

16. Test Specimens and Methods of Testing

16.1 The mechanical tests shall be conducted in accordance with Test Methods and Definitions A 370.

All specimens for mechanical tests shall be taken in the longitudinal direction. This direction of the notch on impact specimens shall be perpendicular to the surface of the material.

16.2 A discard equivalent to the diameter of the bar when heat treated as a solid or a discard equivalent to the wall thickness when heat treated as a seamless tube, bored bar, or hollow forging shall be taken prior to removal of test coupons.

16.2.1 When production pieces are not of sufficient length to permit removal of test coupons in accordance with 16.2, the mid-length of the specimens shall be at the mid-length of the production pieces selected for destruction to provide test coupon material. The production pieces selected for test shall be identical with respect to the quenched contour and size except for length which shall equal or exceed the length of the represented production pieces.

16.3 Tension and impact specimens from bolting materials with cross sections of 1½ in. [38 mm] or less shall be taken so that their longitudinal axis is on a line representing the center of the diameter or thickness.

16.4 Tension test specimens from bolting materials with cross sections exceeding 1½ in. [38 mm] shall be taken so that their longitudinal axis is midway between mid-thickness and surface.

16.5 Impact specimens from bolting materials with cross sections exceeding 1½ in. [38 mm] shall be taken so that their longitudinal axis is midway between mid-thickness and surface or 1 in. [25 mm] below the surface plus the machining allowance per side, whichever is the lesser.

17. Inspection

17.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

18. Rejection

18.1 Material that shows injurious defects or fails to meet properties subsequent to its acceptance at the purchaser's works shall be subject to rejection and the manufacturer shall be notified.

19. Certification

19.1 When requested in the purchaser's order, a test report shall be furnished to the purchaser to indicate the specification, grade, and the test results required by this specification plus any other tests which may be specified in writing by the purchaser. The specification designation included on the test reports shall include year date, and revision letter, if any.

20. Product Marking

20.1 Bars under 2 in. [50 mm] in diameter shall be bundled and tagged with the specification, grade, and mill heat number. The specification number marked on the tag need not include specification year date and revision number.

20.2 Bars 2 in. [50 mm] and over in diameter and all seamless tubes and bored bars shall be die-stamped with the mill heat number and grade on one surface.

20.3 Each hollow forging shall be die-stamped with the heat number or heat symbol code and grade.

20.4 Grade and manufacturer's identification symbols shall be applied to one end of studs ⅜ in. [10 mm] in diameter and larger and to the heads of bolts ¼ in. [6 mm] in diameter and larger. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's symbol marked on the other end.)

20.5 For purposes of identification marking, the manufacturer is considered the organization that certifies the bolting material was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

20.6 *Bar Coding* — In addition to the requirements in 20.1, 20.2, 20.3, 20.4, and 20.5, bar coding is **98**

acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard B-5 02.00 Primary Metals Identification Tag Application. If used on small items, the bar code may be applied to the box or a substantially applied tag.

21. Keywords

21.1 revision letter; signed test report; specification designation; year date

TABLE 1
CHEMICAL REQUIREMENTS[A]

Identification Symbol Grade	B21 (Cr-Mo-V) Chromium-Molybdenum-Vanadium		B22 (4142-H) Chromium-Molybdenum		B23 (E-4340-H) Chromium-Nickel-Molybdenum		B24 (4340 Mod.) Chromium-Nickel-Molybdenum		B24V (4340V Mod.) Chromium-Nickel-Molybdenum-Vanadium	
	Range, %	Product Variation, Over or Under,[B] %	Range, %	Product Variation, Over or Under,[B] %	Range, %	Product Variation, Over or Under,[B] %	Range, %	Product Variation, Over or Under,[B] %	Range, %	Product Variation, Over or Under,[B] %
Carbon	0.36–0.44	0.02	0.39–0.46	0.02	0.37–0.44	0.02	0.37–0.44	0.02	0.37–0.44	0.02
Manganese	0.45–0.70	0.03	0.65–1.10	0.04	0.60–0.95	0.04	0.70–0.90	0.04	0.60–0.95	0.04
Phosphorus, max	0.025[C]	0.005	0.025[C]	0.005	0.025[C]	0.005	0.025[C]	0.005	0.025[C]	0.005
Sulfur, max	0.025[C]	0.005	0.025[C]	0.005	0.025[C]	0.005	0.025[C]	0.005	0.025[C]	0.005
Silicon	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35[D]	0.02
Chromium	0.80–1.15	0.05	0.75–1.20	0.05	0.65–0.95	0.05	0.70–0.95	0.05	0.60–0.95	0.05
Nickel	. . .	. . .	. . .	. . .	1.55–2.00	0.05	1.65–2.00	0.05	1.55–2.00	0.05
Molybdenum	0.50–0.65	0.03	0.15–0.25	0.02	0.20–0.30	0.02	0.30–0.40	0.02	0.40–0.60	0.03
Vanadium	0.25–0.35	0.03	. . .	. . .	. . .	. . .	. . .	. . .	0.04–0.10	0.01

[A] The intentional addition of Bi, Se, Te, and Pb is not permitted.

[B] Unless otherwise specified, separate determinations may vary from the specified ranges, except that elements in any heat must not vary both above and below the specified range.

[C] Phosphorus and sulfur content is 0.04% max when open-hearth steel is specified.

[D] Silicon content is 0.35% max if vacuum-carbon deoxidized.

TABLE 2
MECHANICAL PROPERTY REQUIREMENTS

NOTE 1 — The minimum average of 3 specimens shall not be less than 35 ft · lbf [47 J]. One specimen from a set of 3 may be less than 35 ft·lbf [41 J] but not less than 30 ft · lbf [41 J] .

NOTE 2 — The minimum average of 3 specimens shall not be less than 30 ft · lbf [41J]. One specimen from a set of 3 may be less than 30 ft·lbf [41 J] but not less than 25 ft + lbf [34 J].

NOTE 3 — The minimum average of 3 specimens shall not be less than 25 ft · lbf [34 J]. One specimen from a set of 3 may be less than 25 ft·lbf [34 J] but not less than 20 ft · lbf [27 J].

NOTE 4 — No minimum values established. Tests shall be run for information only.

Grade	Class	Diameter	Tensile Strength, min	Yield Strength, 0.2% offset, min	Elongation, min, %	Reduction of Area, min, %	Surface Brinell Hardness		Charpy V-Notch +10°F (–12.2°C)
							min	max	
			Inch-Pound Units						
		in.	ksi	ksi	In 2 in.				
B21	5	to 2, incl	120	105	15	50	241	285	Note 4
(Cr–Mo–V)		over 2 to 6, incl	115	100	15	50	248	302	Note 4
		over 6 to 8, incl	115	100	15	50	255	311	Note 4
	4	to 3, incl	135	120	13	45	269	331	Note 4
		over 3 to 6, incl	135	120	13	45	277	352	Note 4
	3	to 3, incl	145	130	12	40	293	352	Note 4
		over 3 to 6, incl	145	130	12	40	302	375	Note 4
	2	to 4, incl	155	140	11	40	311	401	Note 4
	1	to 4, incl	165	150	10	35	321	429	Note 4
B22	5	to 2, incl	120	105	15	50	248	293	Note 1
(4142-H)		over 2 to 4, incl	115	100	15	50	255	302	Note 4
	4	to 1, incl	135	120	13	45	269	341	Note 1
		over 1 to 4, incl	135	120	13	45	277	363	Note 4
	3	to 2, incl	145	130	12	40	293	363	Note 4
		over 2 to 4, incl	145	130	12	40	302	375	Note 4
	2	to 3, incl	155	140	11	40	311	401	Note 4
	1	to 1½, incl	165	150	10	35	321	401	Note 4
B23	5	to 6, incl	120	105	15	50	248	311	Note 1
(E-4340-H)		over 6 to 8, incl	115	100	15	50	255	321	Note 1
		over 8 to 9½, incl	115	100	15	50	262	321	Note 4
	4	to 3, incl	135	120	13	45	269	341	Note 1
		over 3 to 6, incl	135	120	13	45	277	352	Note 1
		over 6 to 9½, incl	135	120	13	45	285	363	Note 4
	3	to 3, incl	145	130	12	40	293	363	Note 2
		over 3 to 6, incl	145	130	12	40	302	375	Note 2
		over 6 to 9½, incl	145	130	12	40	311	388	Note 4
	2	to 3, incl	155	140	11	40	311	388	Note 4
		over 3 to 6, incl	155	140	11	40	311	401	Note 4
		over 6 to 9½, incl	155	140	11	40	321	415	Note 4
	1	to 3, incl	165	150	10	35	321	415	Note 4
		over 3 to 6, incl	165	150	10	35	331	429	Note 4
		over 6 to 8, incl	165	150	10	35	341	444	Note 4

TABLE 2 (CONT'D)
MECHANICAL PROPERTY REQUIREMENTS

Grade	Class	Diameter	Tensile Strength, min	Yield Strength, 0.2% offset, min	Elongation, min, %	Reduction of Area, min, %	Surface Brinell Hardness		Charpy V-Notch +10°F (–12.2°C)
							min	max	
			Inch-Pound Units (Continued)						
		in.	ksi	ksi	In 2 in.				
B24	5	to 6, incl	120	105	15	50	248	311	Note 1
(4340 Mod.)		over 6 to 8, incl	115	100	15	50	255	321	Note 1
		over 8 to 9½, incl	115	100	15	50	262	321	Note 1
	4	to 3, incl	135	120	13	45	269	341	Note 1
		over 3 to 6, incl	135	120	13	45	277	352	Note 1
		over 6 to 8, incl	135	120	13	45	285	363	Note 1
		over 8 to 9½, incl	135	120	13	45	293	363	Note 4
	3	to 3, incl	145	130	12	40	293	363	Note 2
		over 3 to 8, incl	145	130	12	40	302	388	Note 2
		over 8 to 9½, incl	145	130	12	40	311	388	Note 4
	2	to 7, incl	155	140	11	40	311	401	Note 2
		over 7 to 9½, incl	155	140	11	40	321	415	Note 4
	1	to 6, incl	165	150	10	35	321	415	Note 3
		over 6 to 8, incl	165	150	10	35	331	429	Note 4
B24V	3	to 4, incl	145	130	12	40	293	363	Note 1
(4340V Mod.)		over 4 to 8, incl	145	130	12	40	302	375	Note 2
		over 8 to 11, incl	145	130	12	40	311	388	Note 3
	2	to 4, incl	155	140	11	40	311	388	Note 2
		over 4 to 8, incl	155	140	11	40	311	401	Note 3
		over 8 to 11, incl	155	140	11	40	321	415	Note 4
	1	to 4, incl	165	150	10	35	321	415	Note 3
		over 4 to 8, incl	165	150	10	35	331	429	Note 4
		over 8 to 11, incl	165	150	10	35	331	444	Note 4
			Metric Units						
		mm	MPa	MPa	In 50 mm				
B21	5	to 50.8, incl	827	724	15	50	241	285	Note 4
(Cr–Mo–V)		over 50.8 to 152.4, incl	793	689	15	50	248	302	Note 4
		over 152.4 to 203.2, incl	793	689	15	50	255	311	Note 4
	4	to 76.2, incl	931	827	13	45	269	331	Note 4
		over 76.2 to 152.4, incl	931	827	13	45	277	352	Note 4
	3	to 76.2, incl	1000	896	12	40	293	352	Note 4
		over 76.2 to 152.4, incl	1000	896	12	40	302	375	Note 4
	2	to 101.6, incl	1069	965	11	40	311	401	Note 4
	1	to 101.6, incl	1138	1034	10	35	321	429	Note 4
B22	5	to 50.8, incl	827	724	15	50	248	293	Note 1
(4142-H)		over 50.8 to 101.6, incl	793	689	15	50	255	302	Note 4
	4	to 25.4, incl	931	827	13	45	269	341	Note 1
		over 25.4 to 101.6, incl	931	827	13	45	277	363	Note 4
	3	to 50.8, incl	1000	896	12	40	293	363	Note 4
		over 50.8 to 101.6, incl	1000	896	12	40	302	375	Note 4
	2	to 76.2, incl	1069	965	11	40	311	401	Note 4
	1	to 38.1, incl	1138	1034	10	35	321	401	Note 4

TABLE 2 (CONT'D)
MECHANICAL PROPERTY REQUIREMENTS

Grade	Class	Diameter	Tensile Strength, min	Yield Strength, 0.2% offset, min	Elongation, min, %	Reduction of Area, min, %	Surface Brinell Hardness		Charpy V-Notch +10°F (–12.2°C)
							min	max	
B23	5	to 152.4, incl	827	724	15	50	248	311	Note 1
(E-4340-H)		over 152.4 to 203.2, incl	793	689	15	50	255	321	Note 1
		over 203.2 to 241.3, incl	793	689	15	50	262	321	Note 4
	4	to 76.2, incl	931	827	13	45	269	341	Note 1
		over 76.2 to 152.4, incl	931	827	13	45	277	352	Note 1
		over 152.4 to 241.3, incl	931	827	13	45	285	363	Note 4
	3	to 76.2, incl	1000	896	12	40	293	363	Note 2
		over 76.2 to 152.4, incl	1000	896	12	40	302	375	Note 2
		over 152.4 to 241.3, incl	1000	896	12	40	311	388	Note 4
	2	to 76.2, incl	1069	965	11	40	311	388	Note 2
		over 76.2 to 152.4, incl	1069	965	11	40	311	401	Note 4
		over 152.4 to 241.3, incl	1069	965	11	40	321	415	Note 4
	1	to 76.2, incl	1138	1034	10	35	321	415	Note 4
		over 76.2 to 152.4, incl	1138	1034	10	35	331	429	Note 4
		over 152.4 to 203.2, incl	1138	1034	10	35	341	444	Note 4
B24	5	to 152.4, incl	827	724	15	50	248	311	Note 1
(4340 Mod.)		over 152.4 to 203.2, incl	793	689	15	50	255	321	Note 1
		over 203.2 to 241.3, incl	793	689	15	50	262	321	Note 1
	4	to 76.2, incl	931	827	13	45	269	341	Note 1
		over 76.2 to 152.4, incl	931	827	13	45	277	352	Note 1
		over 152.4 to 203.2, incl	931	827	13	45	285	363	Note 1
		over 203.2 to 241.3, incl	931	827	13	45	293	363	Note 4
	3	to 76.2, incl	1000	896	12	40	293	363	Note 2
		over 76.2 to 203.2, incl	1000	896	12	40	302	388	Note 2
		over 203.2 to 241.3, incl	1000	896	12	40	311	388	Note 4
	2	to 177.8, incl	1069	965	11	40	311	401	Note 2
		over 177.8 to 241.3, incl	1069	965	11	40	321	415	Note 4
	1	to 152.4, incl	1138	1034	10	35	321	415	Note 3
		over 152.4 to 203.2, incl	1138	1034	10	35	331	429	Note 4
B24V	3	to 101.6, incl	1000	895	12	40	293	363	Note 1
(4340V Mod.)		over 101.6 to 203.2, incl	1000	895	12	40	302	375	Note 2
		over 203.2 to 279.4, incl	1000	895	12	40	311	388	Note 3
	2	to 101.6, incl	1070	965	11	40	311	388	Note 2
		over 101.6 to 203.2, incl	1070	965	11	40	311	401	Note 3
		over 203.2 to 279.4 incl	1070	965	11	40	321	415	Note 4
	1	to 101.6, incl	1140	1035	10	35	321	415	Note 3
		over 101.6 to 203.2, incl	1140	1035	10	35	331	429	Note 4
		over 203.2 to 279.4, incl	1140	1035	10	35	331	444	Note 4

TABLE 3
PERMISSIBLE VARIATION IN DIAMETER OF ROLLED BARS[A]

Specified Diameter, in. [mm]	Size Tolerance				Out-of-Round	
	Over		Under			
	in.	mm	in.	mm	in.	mm
1 to 1 1/8 [25 to 29], incl	0.010	0.25	0.010	0.25	0.015	0.38
Over 1 1/8 to 1 1/4 [29 to 32], incl	0.011	0.28	0.011	0.28	0.016	0.41
Over 1 1/4 to 1 3/8 [32 to 35], incl	0.012	0.30	0.012	0.30	0.018	0.46
Over 1 3/8 to 1 1/2 [35 to 38], incl	0.014	0.36	0.014	0.36	0.021	0.53
Over 1 1/2 to 2 [38 to 50], incl	1/64	0.4	1/64	0.4	0.023	0.58
Over 2 to 2 1/2 [50 to 65], incl	1/32	0.8	0		0.023	0.58
Over 2 1/2 to 3 1/2 [65 to 90], incl	3/64	1.2	0		0.035	0.89
Over 3 1/2 to 4 1/2 [90 to 115], incl	1/16	1.6	0		0.046	1.17
Over 4 1/2 to 5 1/2 [115 to 140], incl	5/64	1.9	0		0.058	1.47
Over 5 1/2 to 6 1/2 [140 to 165], incl	1/8	3.2	0		0.070	1.78
Over 6 1/2 to 8 1/4 [165 to 210], incl	5/32	3.7	0		0.085	2.16
Over 8 1/4 to 9 1/2 [210 to 240], incl	3/16	4.8	0		0.100	2.54

[A] Consult the manufacturer on forged bars, cold-finished bars, bored bars, seamless tubes, and forged hollows.

TABLE 4
ROLLED BARS[A] — PERMISSIBLE GRINDING DEPTH FOR REMOVAL OF SURFACE DEFECTS

Diameter, in. [mm]	Minimum Stock Removal Per Side	
	in.	mm
1 to 1 1/8 [25 to 29], incl	0.025	0.64
Over 1 1/8 to 1 1/4 [29 to 32], incl	0.028	0.71
Over 1 1/4 to 1 3/8 [32 to 35], incl	0.030	0.76
Over 1 3/8 to 1 1/2 [35 to 38], incl.	0.033	0.84
Over 1 1/2 to 2 [38 to 50], incl	0.042	1.07
Over 2 to 2 1/2 [50 to 65], incl	0.052	1.32
Over 2 1/2 to 3 1/2 [65 to 90], incl	0.072	1.83
Over 3 1/2 to 4 1/2 [90 to 115], incl	0.090	2.29
Over 4 1/2 to 5 1/2 [115 to 140], incl	0.110	2.79
Over 5 1/2 to 6 1/2 [140 to 165], incl	0.125	3.18
Over 6 1/2 to 8 1/4 [165 to 210], incl	0.155	3.94
Over 8 1/4 to 9 1/2 [210 to 240], incl	0.203	5.16

[A] Consult the manufacturer on forged bars, cold-finished bars, bored bars, seamless tubes, and forged hollows.

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order, in which event the tests shall be made at the mill at the purchaser's expense unless otherwise agreed upon.

S1. Product Analysis

S1.1 Product analysis shall be made on each bar, seamless tube, bored bar, or the parent bar from which forged hollows are made. Individual pieces failing to conform to Section 7 shall be rejected.

S2. Macroetch Test

S2.1 The material shall be macroetch tested and shall meet the quality and cleanliness requirements as specified by the purchaser. The macroetch examination may be made on representative billets from which the material will be produced or it may be made on samples cut from the ends of the bars, seamless tubes, bored bars, or forged hollows. The samples shall be prepared in accordance with the procedure described in Method E 381.

NOTE 1 — The quality and cleanliness may be specified by the purchaser as equal to or better than that indicated by a designated letter and plate number of Military Standard—430 (latest revision).

S3. Ultrasonic Test

S3.1 Each length shall be ultrasonically inspected in a manner agreeable to the purchaser and supplier.

S4. Demonstration of Capability

S4.1 When annealed material is ordered to 5.1, a sample piece at least 3 *D* long of a representative bar shall be heat treated in accordance with 5.2 and 5.3. Mechanical test samples taken as required by Section 16 shall meet the requirements of 8.2 and 10.2.

S5. Fracture Tension Temperature

S5.1 The fracture transition temperature for a 50% fibrous (ductile shear) fracture shall be determined. The procedure for determination of the fracture transition temperature shall be to prepare four sets (three to a set) of Charpy V-notch specimens in accordance with Section 16. One set of three specimens shall be tested at approximately 70°F [20°C]. The absorbed energy in foot-pounds shall be recorded and the percent of fibrous fracture determined from Table S1.1. The other three sets shall be tested at successively lower or higher temperatures to bracket the temperature where the material will exhibit a 50% fibrous fracture. The results of all test data are to be reported to the purchaser.

S6. Magnetic Particle Inspection

S6.1 Material may be supplied to cleanliness requirements by agreement between the purchaser and supplier. The cleanliness shall be determined by the magnetic particle method described in the latest issue of Practice E 45.

NOTE 2 — The material shall have the minimum stock removal specified in Table S1.2 prior to magnetic particle inspection.

S7. Elevated Temperature Test

S7.1 Three Charpy V-notch specimens shall be tested at 212°F [100°C] to determine the "upper shelf" fracture energy of the material. No specimen thus tested shall break at an energy less than 30 ft · lbf [41 J].

S8. Alternative Fracture Toughness Requirement

S8.1 The fracture toughness requirements (Charpy impact test) for material of the ASME Boiler and Pressure Vessel Code, Section III, Subarticle NB-2300, shall be used instead of the Charpy impact test requirement specified in Table 2.

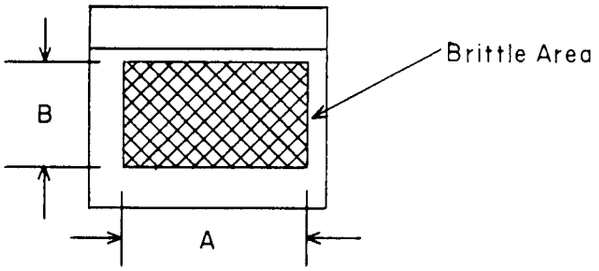
S9. Marking

S9.1 Grade and manufacturer's identification symbols shall be applied to one end of the studs and to the heads of bolts of all sizes. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts and studs smaller than $\frac{1}{4}$ in. [6 mm] in diameter and for $\frac{1}{4}$ in. [6 mm] studs requiring more than a total of three symbols, the marking shall be a matter of agreement between the purchaser and manufacturer.

TABLE S1.1
PERCENT FIBROUS FRACTURE[A]
Dimension *A* Width, mm

	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
Dimension *B* Height, mm																		
1.0	98	98	97	96	96	95	94	94	93	93	92	91	91	90	89	89	88	87
1.5	97	96	95	94	93	93	92	91	90	89	88	87	86	85	85	83	82	81
2.0	96	95	94	93	91	90	89	88	86	85	84	82	81	80	79	78	76	75
2.5	95	94	92	91	89	87	86	84	83	81	80	79	76	75	73	72	70	69
3.0	94	93	91	90	87	85	83	81	79	78	76	74	72	70	68	66	64	63
3.5	93	91	89	87	85	83	80	78	75	74	72	69	67	65	63	61	58	56
4.0	93	90	87	85	83	80	78	75	72	70	68	65	62	60	57	55	52	50
4.5	92	89	86	83	80	78	75	72	69	66	63	61	58	55	52	49	46	43
5.0	91	88	84	81	78	75	72	69	66	63	59	56	53	50	48	44	40	38
5.5	90	86	83	79	75	72	69	66	63	59	55	52	48	45	42	38	35	31
6.0	89	85	81	78	74	70	66	63	59	55	51	47	44	40	36	33	29	25
6.5	88	84	80	76	72	68	63	59	55	51	47	43	40	35	31	27	23	19
7.0	87	82	79	74	69	65	61	56	52	47	43	39	34	30	26	21	16	12
7.5	86	81	76	72	67	62	58	53	48	44	40	34	30	25	23	16	11	6
8.0	85	80	75	70	65	70	55	50	45	40	35	30	25	20	15	10	5	0

[A] Calculation of Percent Fibrous Area:



Measure Dimensions *A* and *B* to the nearest ½ mm.

TABLE S1.2
ROLLED BARS[A] — STOCK REMOVAL FOR MAGNETIC PARTICLE INSPECTION

Diameter, in. [mm]	Minimum Stock Removal Per Side	
	in.	mm
1 to 1½ [25 to 38], incl	0.075	1.90
Over 1½ to 2 [38 to 50], incl	0.090	2.29
Over 2 to 2½ [50 to 65], incl	0.125	3.18
Over 2½ to 3½ [65 to 90], incl	0.156	3.96
Over 3½ to 4½ [90 to 115], incl	0.187	4.75
Over 4½ to 6 [115 to 155], incl	0.250	6.35
Over 6 to 10 [155 to 255], incl	0.312	7.92

[A] Consult the manufacturer on forged bars, cold-finished bars, bored bars, seamless tubes, and forged hollows.

SPECIFICATION FOR QUENCHED AND TEMPERED CARBON AND ALLOY STEEL FORGINGS FOR PRESSURE VESSEL COMPONENTS

SA-541/SA-541M

(Identical with ASTM Specification A 541/A 541M-95.)

1. Scope

1.1 This specification covers requirements for quenched and tempered carbon and alloy steel forgings for pressure vessel components.

1.2 All grades are considered weldable under proper conditions. Welding technique is of fundamental importance, and it is presupposed that welding procedure and inspection will be in accordance with approved methods for the grade of material used.

NOTE 1 — Grades 1 and 1A have different chemistries but the same mechanical requirements.

NOTE 2 — Designations have been changed as follows:

Current	Formerly
Grade 1	Class 1
Grade 1A	Class 1A
Grade 1C	Class 4
Grade 2 Class 1	Class 2
Grade 2 Class 2	Class 2A
Grade 3 Class 1	Class 3
Grade 3 Class 2	Class 3A
Grade 4N Class 1	Class 7
Grade 4N Class 2	Class 7A
Grade 4N Class 3	Class 7B
Grade 5 Class 1	Class 8
Grade 5 Class 2	Class 8A
Grade 11 Class 4	Class 11C
Grade 22 Class 3	Class 22B
Grade 22 Class 4	Class 22C
Grade 22 Class 5	Class 22D
Grade 22V	Class 22V
Grade 3V	Class 3V

1.3 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as the standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Methods for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 788 Specification for Steel Forgings, General Requirements

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order a detailed drawing that locates areas of significant loading in the forging (when required); the method of selecting test locations (see

6.2); purchase option (if any) in accordance with 9.1, and any supplementary requirements desired.

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with requirements of Specification A 788, the requirements of this specification shall prevail.

4. Chemical Composition

4.1 *Heat Analysis* — The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1 except that the additional features of Supplementary Requirements S8, S9, S10, S12, and S15 shall also apply as individually specified in the ordering information.

4.2 *Product Analysis* — The manufacturer shall use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat. The permissible variations of Table 1 of Specification A 788 do not apply to carbon, phosphorus, silicon and sulphur for all classes, vanadium for Grade 1C and columbium and calcium for Grades 22V and 3VCb. Boron is not subject to product analysis. The purchaser may also make this determination in accordance with Specification A 788.

5. Heat Treatment for Mechanical Properties

5.1 After complete austenization, the forgings shall be quenched in a suitable liquid medium by spraying or immersion. For Grade 22V forgings, the minimum austenitizing temperature shall be 1650°F [900°C]. Quenching shall be followed by tempering at a subcritical temperature and holding at this temperature for a minimum time of ½ h/in. [25 mm] of maximum section thickness. Minimum tempering temperatures shall be:

Grade	°F [°C]
1, 1A, 2 Class 2, 3 Class 2	1150 [620]
2, 3, Class 2, 22 Class 3	1200 [650]
1C, 11 Class 4, 22 Class 4, 4N Class 1, 4N Class 2, 5 Class 1, 5 Class 2	1100 [595]
22 Class 15	1050 [565]
4N Class 3	1125 [610]
3V	1250 [675]
22V	1250 [675]

5.2 For Classes 1, 1A, 2, 2A, 3, or 3A, a multiple stage austenitizing procedure may be used whereby the forging is first fully austenitized and liquid quenched, followed by reheating within the intercritical temperature range to partially reaustenitize, and again liquid quenched. On completion of the austenitizing/quenching cycles, the forgings shall be tempered at a subcritical temperature as described in 4.1.

6. Mechanical Properties

6.1 *General Requirements* — The forgings shall conform to the requirements of Table 2. The forgings shall also conform to the requirements of Table 3 unless either Supplementary Requirement S6 or S13 is specified, in which case the requirements of those sections shall apply. The largest obtainable tension test specimen as specified in Fig. 4 of Test Methods and Definitions A 370 shall be used. Impact specimens shall be Charpy V-notch, Type A, as shown in Fig. 10 of Test Methods and Definitions A 370. The usage of subsize impact specimens due to material limitations must have prior purchaser approval.

6.2 *Sampling* — The longitudinal axis and mid-length of tension and impact test specimens shall be positioned in accordance with one of the following methods as specified by the purchaser:

6.2.1 *Method 1* — This method shall always be used when the maximum quenched thickness does not exceed 2 in. [50 mm]. Specimens shall be located in the production forging or test forging (as described in Method 4) at mid-thickness and at least 2 in. from other quenched surfaces.

6.2.2 *Method 2* — t by 2t, where t is the distance from the area of significant loading (see 3.1) to the nearest quenched surface. However, the specimens shall not be nearer to one quenched surface than ¾in. [20 mm] and to the second quenched surface than 1½in. [40 mm]. When this method of testing is employed, forgings are usually manufactured in accordance with a purchaser-approved drawings showing pre-quenched dimensions and the location of mechanical test specimens.

6.2.3 *Method 3* — ¼T by T, where T is the maximum thickness of the forging as heat treated. Where this method of testing is employed, the following limitations for as-treated thickness shall apply, unless otherwise agreed upon:

Grade	in. [mm], max
1 and 1A	3 [75]
2 Class 2 and 3 Class 2	6 [150]
2 Class 1 and 3 Class 1	8 [205]
1C	4 [100]
11 Class 4	5 [125]
22 Class 4, 4N Class 2, 5 Class 2	6 [150]
22 Class 5	8 [205]
4N Class 1, 5 Class 1, 4N Class 3, 3V, 3VCb, 22V, and 22 Class 3	10 [255]

6.2.4 *Method 4* — Test specimens shall be taken from a representative separate test forging or bar made from the same heat of steel which shall receive substantially the same reduction and type of hot working as the production forgings which it represents, except that a longitudinally forged bar may be used to represent a rolled ring of similar cross section. It shall be of the same nominal thickness as the as-quenched production forgings and shall be heat treated in the same furnace charge and under the same conditions as the production forgings. Test specimens shall be removed using the $\frac{1}{4}T$ by T procedure referenced in Method 3 with the same limitation on forging thickness as in 6.2.3. This method shall be limited to forgings with a rough machined weight of not more than 1000 lb [455 kg].

6.3 *Metal Buffers* — The required distances from quenched surfaces may be obtained with metal buffers instead of integral extensions. Buffer material may be carbon or low-alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at least $\frac{1}{2}$in. [13 mm] from the buffered surface of the forging. Buffers shall be removed and the welded area subjected to magnetic particle test to ensure freedom from cracks unless the welded areas are completely removed by subsequent machining.

6.4 Samples shall be removed from forgings after the quenching and tempering heat treatments. This sample material shall be subjected to a simulated post-weld heat treatment if supplementary requirement S1 is specified.

6.5 *Orientation* — For upset disk forgings, the longitudinal axis of all test specimens shall be oriented in the tangential direction. For all other forgings, the longitudinal axis of the specimens shall be oriented in the direction of maximum working of the forging unless Supplementary Requirements S11 or S14 are imposed.

6.6 *Number of Tests:*

6.6.1 *Forgings under 500 lb* [*230 kg*] *As Treated* — For duplicate forgings weighing less than 500 lb as treated, one tension test and one impact test (three specimens) shall be made to represent each heat in each heat-treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature control and equipped with recording pyrometers so that complete heat-treatment records are available, a heat-treatment charge shall be considered as any continuous run not exceeding an 8-h duration.

6.6.2 *Forgings weighing 500 to 10 000 lb* [*230 to 435 kg*] *As-Heat Treated* — One tension and one impact test (3 specimens) shall be made for each forging.

6.6.3 Each forging weighing over 10 000 lb [4535 kg] shall require two tension tests and two impact tests, located at opposite ends if the length is $1\frac{1}{2}$ times the diameter or more, or 180 deg apart otherwise.

7. Repair Welding

7.1 Repair welding of forgings may be permitted, but only at the option of the purchaser.

7.2 If repair welding is performed, welders and weld procedures shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

8. Workmanship and Quality Level Requirements

8.1 Dimensional and visual inspections shall be conducted by the manufacturer. Forgings shall be free of cracks, thermal ruptures, or other imperfections.

9. Certification and Reports

9.1 In addition to items required to be reported by Specification A 788, the following items shall also be reported:

9.1.1 Product chemical analysis.

9.1.2 The method used for locating test specimens.

9.1.3 Sketches included in the report of nondestructive examinations.

9.1.4 Details of the heat treatment cycle, as listed in Specification A 788.

10. Product Marking

10.1 The purchaser may specify additional identification marking and the location of the marking. If stamps are used, they shall be round-nosed or "interrupted-dot" die stamps having a minimum radius of $\frac{1}{32}$ in. [.8 mm].

11. Keywords

11.1 chromium-molybdenum steel; nickel-chromium-molybdenum alloy steel; pressure vessel service; quenched and tempered steel; steel forgings — alloy; steel forgings — carbon

TABLE 1
CHEMICAL REQUIREMENTS COMPOSITION, %

	Grade 1	Grade 1A	Grade 2	Grade 3	Grade 1C	Grade 11 Class 4	Grade 22 Classes 4 and 5	Grade 4N	Grade 5	Grade 3V	Grade 22 Class 3	Grade 22V	Grade 3VCb
Carbon	0.35 max	0.30 max	0.27 max	0.25 max	0.18 max	0.10–0.20	0.05–0.15	0.23 max	0.23 max	0.10–0.15	0.11–0.15	0.11–0.15	0.10–0.15
Manganese	0.40–0.90	0.70–1.35	0.50–0.90	1.20–1.50	1.30 max	0.30–0.80	0.30–0.60	0.20–0.40	0.20–0.40	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60
Phosphorus	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.020 max	0.015 max	0.015 max	0.020 max
Sulfur	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.025 max	0.020 max	0.015 max	0.010 max	0.010 max
Silicon[1]	0.15–0.35	0.15–0.40	0.15–0.35	0.15–0.35	0.15–0.35	0.50–1.00	0.50 max	0.30 max	0.30 max	0.10 max	0.50 max	0.10 max	0.10 max
Nickel	0.40 max	0.40 max	0.50–1.00	0.40–1.00	0.25 max	0.50 max	0.50 max	2.8–3.9	2.8–3.9	. . .	0.25 max	0.25 max	0.25 max
Chromium	0.25 max	0.25 max	0.25–0.45	0.25 max	0.15 max	1.00–1.50	2.00–2.50	1.25–2.00	1.25–2.00	2.8–3.3	2.00–2.50	2.00–2.50	2.7–3.3
Molybdenum	0.10 max	0.10 max	0.55–0.70	0.45–0.60	0.05 max	0.45–0.65	0.90–1.10	0.40–0.60	0.40–0.60	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10
Vanadium	0.05 max	0.05 max	0.05 max	0.05 max	0.02–0.12	0.05 max	0.05 max	0.03 max	0.08 max	0.20–0.30	0.02 max	0.25–0.35	0.20–0.30
Titanium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.015–0.035	. . .	0.030 max	0.015 max
Boron	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.001–0.003	. . .	0.0020 max	. . .
Copper	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.20 max	0.25 max
Columbium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.07 max	0.015–0.070
Calcium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.015 max[2]	0.0005-0.0150

NOTES:
(1) When vacuum carbon-deoxidation is required for the classes included in Supplementary Requirements S10, the silicon content shall be 0.10% max.
(2) For Grade 22V, rare earth metals (REM) may be added in place of calcium, subject to agreement between the producer and the purchaser. In that case the total amount of REM shall be determined and reported.

TABLE 2
TENSILE REQUIREMENTS

	Grades 1 and 1A	Grades 2 Class 1, 3 Class 1, 1C and 11 Class 4	Grade 2 Class 2 and Grade 3 Class 2	Grade 22 Class 4	Grade 22 Class 5	Grade 4N Class 1 and Grade 5 Class 1	Grades 4N Class 2 and 5 Class 2	Grade 4N Class 3	Grades 3V and 22V	Grade 22 Class 3	Grade 3VCb
Tensile strength, ksi [MPa]	70 to 95 [485–660]	80 to 105 [550–720]	90 to 115 [620–790]	105–130 [720–900]	115–140 [790–1000]	105 to 130 [720–900]	115–140 [790–1000]	90 to 115 [620–790]	85–110 [585–760]	85–110 [585–760]	85–110 [585–760]
Yield strength (0.2% offset), min, ksi [MPa]	36 [250]	50 [340]	65 [450]	85 [590]	100 [690]	85 [590]	100 [690]	70 [480]	60 [415]	55 [380]	60 [415]
Elongation in 2 in. or 50 mm, min, %	20	18	16	16	15	18	16	20	18	18	18
Reduction of area, min, %	38	38	35	45	40	48	45	48	45	45	45

TABLE 3
CHARPY V-NOTCH IMPACT REQUIREMENTS AT 40°F (4°C) (EXCEPT FOR 2A)[1, 2]

	Grades 1, 1A, and 11 Class 4	Grade 2 Class 2 and 3 Class 2	Grade 2 Class 1, 3 Class 1 and 1C	Grade 22 Class 5	Grades 22 CL 4 4N Classes 1, 2, 3, 5 Classes 1,2	Grades 3V and 3VCb, Grade 22, Class 3 and Grade 22V
Minimum average value of set of three specimens, ft·lbf (J)[3]	15 [20]	35 [47][4]	30 [41]	25 [34]	35 [47]	40 [55][5]
Minimum value of one specimen, ft·lbf (J)	10 [14]	30 [41][4]	25 [34]	20 [27]	30 [41]	35 [50][5]

NOTES:
(1) These Charpy values are for tests made on standard 10-mm square specimens. If sub-size impact specimens are used, the required minimum ft·lbf values shall be determined by multiplying the ft·lbf values in Table 3 by $^{5}/_{6}$ for 7.5 by 10-mm specimens, and by $^{2}/_{3}$ for 5 by 10-mm specimens.
(2) These values apply for tests at lower temperatures if Supplementary Requirement S6 is specified in the order.
(3) Not more than one specimen from a set may be below this value.
(4) Tested at 70°F [21°C].
(5) Tested at 0°F [−18°C].

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Simulated Post-Weld Heat Treatment of Mechanical Test Samples

S1.1 All test coupons shall be subjected to single or multiple heat treatment at subcritical temperatures prior to testing. Such treatments are intended to simulate post-weld or other treatments to which the forgings will be subjected during subsequent fabrication. The purchaser shall furnish the manufacturer with details of the desired heat treatment for the test coupons, including temperatures, times, and cooling rates.

S2. Ultrasonic Inspection

S2.1 Forgings shall be ultrasonically examined in accordance with the procedures of Practice A 388/A388M.

S2.1.1 *Longitudinal Wave Test:*

S2.1.1.1 Unless otherwise specified, the back reflection method of tuning shall be used in accordance with Procedure Section (the paragraph regarding Back-Reflection Technique) of Practice A 388/A 388M.

S2.1.1.2 In addition to the reportable conditions of the Recording Section of Practice A 388/A 388M, indications exceeding the resultant back reflection shall be recorded.

S2.1.1.3 The following conditions are subject to rejection:

(*a*) Complete loss of back reflection accompanied by an indication of a discontinuity. For this purpose, a back reflection less than 5% of full screen height shall be considered complete loss of back reflection.

(*b*) An indication equal in amplitude to that of the back reflection established in an indication-free portion of the forging.

S2.1.2 *Angle Beam Test:*

S2.1.2.1 Calibration notches, calibration reference, and method of scanning shall be in accordance with the Procedure Section (the paragraph regarding Angle-Beam Examination) of Practice A 388/A 388M.

S2.1.2.2 A forging that contains a discontinuity which results in an indication exceeding the amplitude of the reference line is subject to rejection.

S2.1.3 The report of the ultrasonic examination shall be in compliance with the Report Section of Practice A 388/A 388M.

S2.1.4 Additional nondestructive examination or trepanning may be employed to resolve questions of interpretation of ultrasonic indications. The manufacturer shall accept responsibility for injurious conditions that will not be removed in final machining.

S3. Magnetic Particle Examination

S3.1 Each forging shall be inspected by magnetic particle methods described in Method A 275/A 275M. Acceptance and rejection standards shall be mutually agreed upon by the purchaser and manufacturer.

S4. Charpy V-Notch Impact Transition Curve

S4.1 Sufficient impact tests shall be made from the forging test material to establish a temperature-absorbed energy curve. The test temperature range shall be wide enough to establish the upper and lower shelf foot pound energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

S5. Additional Charpy Data

S5.1 The percent shear fracture and mils or millimetres of lateral expansion, defined in Test Methods and Definitions A 370, shall be reported for each Charpy specimen tested.

S6. Charpy Impact Tests

S6.1 Charpy impact tests shall be made in accordance with the provisions of Section 6 of this specification

except that the test temperature shall be lower than that specified in Table 3.

S7. Drop-Weight Test

S7.1 Drop-weight test shall be conducted in accordance with the requirements of Test Method E 208. The fracture plane of the specimens shall coincide with the location required for other mechanical test specimens as specified by the purchaser in accordance with 6.2. However, since the drop-weight specimen can be taken in any orientation, the fracture plane of the specimen when tested to Method 2 (6.2.2) shall be a minimum distance of $^{7}/_{16}$ in. [11 mm] from the nearest quenched surface, and $1^{1}/_{2}$ in. [40 mm] from any second surface. The purchaser may specify either duplicate no-break performance when tested 10 deg warmer than a specified temperature or request a determination of the nil-ductility temperature.

S8. Restrictive Chemistry for Grades 4N and 5

S8.1 Phosphorus and sulfur limits for Grades 4N and 5 may be specified 0.020%, max.

S9. Additional Vanadium

S9.1 For Grade 5 forgings 0.05 to 0.15% vanadium may be specified.

S10. Special Steels

S10.1 Vacuum treated steel shall be specified.

S10.2 When Grades 2, 3, 4N, and 5 are vacuum carbon deoxidized, the silicon content shall be 0.10% maximum.

S10.3 The test report shall indicate that the steel was vacuum carbon deoxidized.

S11. Rings and Hollow Cylindrically Shaped Parts

S11.1 Tests shall be removed in the tangential (circumferential) direction regardless of direction of maximum working.

S12. Restrictive Chemistry

S12.1 The following restricted phosphorus and copper limits may be specified as follows:

(*a*) P 0.012% max heat, 0.015% max product; Cu 0.10% max,

(*b*) P 0.015% max heat, 0.018% max product; Cu 0.15% max.

S13. Alternative Fracture Toughness Requirements

S13.1 The fracture toughness requirements (drop-weight or Charpy impact tests, or both) for materials of the ASME Boiler and Pressure Vessel Code, Section III, Article NB-2300, NC-2300, ND-2300, NE-2300, NF-2300 or NG-2300, as specified, shall be used instead of the Charpy impact test requirements of this specification.

S14. Alternative Test Specimen Orientation

S14.1 The longitudinal axis of all test specimens shall be oriented in a direction transverse to the direction of maximum working of the forging.

S15. Restricted Sulfur Content

S15.1 The sulfur content shall be limited to 0.015% maximum heat and 0.018% maximum product.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, QUENCHED-AND-TEMPERED, CHROMIUM-MOLYBDENUM, AND CHROMIUM-MOLYBDENUM-VANADIUM

SA-542/SA-542M

(Identical with ASTM Specification A 542/A 542M-95.)

1. Scope

1.1 This specification covers two types of 2¼Cr-1 Mo and three types of Cr-Mo-V alloy steel plates for use in the quenched-and-tempered condition, intended for the fabrication of welded pressure vessels and components.

1.2 Material under this specification is available in five types, designated "A," "B," "C," "D," and "E." Type B is identical to Type A except for restrictive limits for carbon, phosphorus, sulfur, and nickel. The material is also available in five classes having the following strength levels. Type E is available only as Class 4 and 4a.

Class	Minimum Tensile Strength, ksi [MPa]
1	105 [725]
2	115 [795]
3	95 [655]
4 and 4a	85 [585]

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements.

1.4 The minimum thickness of plates is limited to 3/16 in. [5 mm].

1.5 The material is intended to be suitable for fusion welding. Welding technique is of fundamental importance and it is presupposed that welding procedures will be in accordance with approved methods.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents, therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions,

and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information which should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the supplementary requirements listed in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be heat treated by heating to a suitable austenitizing temperature, holding for a sufficient period of time to attain uniform temperature throughout the thickness, and quenching in a suitable liquid medium by spraying or immersion. For Type D material, the minimum austenitizing temperature shall be 1650°F [900°C]. For Type E material, the minimum austenitizing temperature shall be 1850°F [1010°C].

5.2 After quenching, the plates shall be tempered to produce the specified tensile requirements by heating to a suitable temperature and holding for a period of time of not less that 30 min/in. [1.2 min/mm] of thickness but not less than ½ h. The minimum tempering temperature shall be as follows:

Type	Class	Temperature, °F [°C]
A, B, C	1, 2, 3	1050 [565]
A, B, C	4	1200 [650]
A, B, C, D	4a	1250 [675]

5.3 Plates over 4 in. [100 mm] in thickness shall receive a prior heat treatment of normalizing at, or water quenching from, a temperature within the range from 1650 to 1850°F [900 to 1010°C] for Types A, B, C, and D and 1850 to 2050°F [1010 to 1120°C] for Type E before the heat treatment specified in 5.1.

5.4 When the purchaser elects to perform the heat treatment required above, the material manufacturer shall temper the plates prior to shipment at a temperature not lower than 1050°F [565°C] for Types A, B, C, and D and not lower than 1200°F [650°C] for Type E.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements shown in Table 1.

7. Mechanical Properties

7.1 *Tension Test Requirements:*

7.1.1 The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.1.2 For nominal plate thicknesses of ¾ in. [20 mm] and under, the 1½ in. [40 mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation.

7.2 *Notch Toughness Requirements — Classes 4 and 4a:*

7.2.1 A transverse Charpy V-notch test from each plate as-heat-treated shall have a minimum energy absorption value of 40 ft · lbf [54 J] average of three specimens and 35 ft · lbf [48 J] for one specimen only in the set.

7.2.2 For Class 4, the impact test temperature shall be as specified on the order.

7.2.3 For Class 4a, the impact test temperature shall be 0°F [−18°C].

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %				
	Type A	Type B	Type C	Type D	Type E
Carbon:					
Heat analysis	0.15 max	0.11–0.15	0.10–0.15	0.11–0.15	0.10–0.15
Product analysis	0.18 max[A]	0.09–0.18	0.08–0.18	0.09–0.18	0.06–0.18
Manganese:					
Heat analysis	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60
Product analysis	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66	0.25–0.66
Phosphorus, max	0.025[B]	0.015[B]	0.025[B]	. . .	0.025
Heat analysis	. . .	. . .	. . .	0.015	. . .
Product analysis	. . .	. . .	. . .	0.020	. . .
Sulfur, max	0.025[B]	0.015[B]	0.025[B]	. . .	0.010
Heat analysis	. . .	. . .	. . .	0.010	. . .
Product analysis	. . .	. . .	. . .	0.015	. . .
Silicon, max	0.50[B]	0.50[B]	0.13[B]	. . .	0.15
Heat analysis	. . .	. . .	. . .	0.010	. . .
Product analysis	. . .	. . .	. . .	0.013	. . .
Chromium:					
Heat analysis	2.00–2.50	2.00–2.50	2.75–3.25	2.00–2.50	2.75–3.25
Product analysis	1.88–2.62	1.88–2.62	2.63–3.37	1.08–2.62	2.63–3.37
Molybdenum:					
Heat analysis	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10	0.90–1.10
Product analysis	0.85–1.15	0.85–1.15	0.85–1.15	0.85–1.15	0.85–1.15
Copper, max:					
Heat analysis	0.40	0.25	0.25	0.20	0.25
Product analysis	0.43	0.28	0.28	0.23	0.28
Nickel, max:					
Heat analysis	0.40	0.25	0.25	0.25	0.25
Product analysis	0.43	0.28	0.28	0.28	0.28
Vanadium:					
Heat analysis	0.03 max	0.02 max	0.20–0.30	0.25–0.35	0.20–0.30
Product analysis	0.04 max	0.03 max	0.18–0.33	0.23–0.37	0.18–0.33
Titanium:					
Heat analysis	. . .	. . .	0.015–0.035	0.030	. . .
Product analysis	. . .	. . .	0.005–0.045	0.035	. . .
Boron:					
Heat analysis	. . .	. . .	0.001–0.003	0.0020	. . .
Product analysis	. . .	. . .	NA[C]	NA[C]	. . .
Columbium, max:					
Heat analysis	. . .	. . .	. . .	0.07	0.015–0.070
Product analysis	. . .	. . .	. . .	0.08	0.010–0.075
Calcium, max:[D]					
Heat analysis	. . .	. . .	. . .	0.015	0.0005–0.0150
Product analysis	. . .	. . .	. . .	0.020	NA[C]

[A] In A 542/A 542M – 82 and earlier editions, for plates 5 in. [125 mm] and under in thickness, the carbon was limited to 0.15% maximum.
[B] Applies to both heat analysis and product analysis.
[C] NA = Product analysis in *not applicable.*
[D] Rare earth metals (REM) may be added in place of calcium, subject to agreement between the producer and the purchaser. In that case, the total amount of REM shall be determined and reported.

TABLE 2
TENSILE REQUIREMENTS

	Class 1	Class 2	Class 3	Class 4	Class 4a
Tensile strength, ksi [MPa]	105–125 [725–850]	115–135 [795–930]	95–115 [655–795]	85–110 [586–760]	85–110 [585–760]
Yield strength, min, ksi [MPa]	85 [585]	100 [690]	75 [515]	55 [380]	60 [415]
Elongation in 2 in. [50 mm], min, %	14	13	20	20	18

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed in this section by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.2 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S10. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S11. Ultrasonic Examination in accordance with Specification A 578/A 578M, and

S12. Bend Test.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, QUENCHED AND TEMPERED, NICKEL-CHROMIUM-MOLYBDENUM

SA-543/SA-543M

(Identical with ASTM Specification A 543/A 543M-93)

1. Scope

1.1 This specification covers nickel-chromium-molybdenum alloy steel plates for use in the quenched and tempered condition, intended for the fabrication of welded pressure vessels and other pressure equipment. These alloy compositions are normally considered for construction involving plate thicknesses of 2 in. [50 mm] or greater.

1.2 Material under this specification is available in two types, B and C. The material is also available in three classes as follows:

Class	Minimum Tensile Strength, ksi [MPa]
1	105 [725]
2	115 [795]
3	90 [620]

1.3 The maximum thickness of plates is limited only by the capacity of the chemical composition to meet the specified mechanical property requirements.

1.4 The minimum plate thickness is $^{3}/_{16}$ in. [5 mm].

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A20/A 20M also establishes the rules for the ordering information which should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are

available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be heat treated by heating to a suitable austenitizing temperature, holding for a sufficient time period to attain uniform temperature through the thickness and quenching in a suitable liquid medium by spraying or immersion. The plates shall then be tempered to produce the required properties by heating to a suitable temperature not lower than 1100°F [595°C] with a holding time of not less than ½ h/in. [1.2 min/mm] of thickness but not less than ½ h.

5.2 Plates over 4 in. [100 mm] in thickness shall receive a prior treatment of normalizing at, or water quenching from a temperature within the range from 1650 to 1850°F [900 to 1010°C] before the heat treatment specified in 5.1.

5.3 When the fabricator elects to perform the heat treatment in 5.1 and 5.2, the manufacturer shall temper the plates prior to shipment at a temperature not lower than 1100°F [595°C].

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements:*

7.1.1 The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

7.1.2 For nominal plate thicknesses of ¾ in. [20 mm] and under, the 1½ in. [40 mm] wide rectangular specimen may be used for the tension test and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and shows the greatest elongation.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %	
	Type B	Type C
Carbon, max[A]	0.20	0.18
Manganese, max[A]	0.40	0.40
Phosphorus, max[A]	0.020	0.020
Sulfur, max[A]	0.020	0.020
Silicon:		
Heat analysis	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45
Nickel:		
Heat analysis	2.25–4.00	2.00–3.50
Product analysis	2.18–4.07	1.93–3.57
Chromium:		
Heat analysis	1.00–1.90	1.00–1.90
Product analysis	0.94–1.96	0.94–1.96
Molybdenum:		
Heat analysis	0.20–0.65	0.20–0.65
Product analysis	0.16–0.69	0.16–0.69
Vanadium, max[A]	0.03	0.03

[A] Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

	Class 1	Class 2	Class 3
Tensile strength, ksi [MPa]	105–125 [725–860]	115–135 [795–930]	90–115 [620–795]
Yield strength, min, ksi [MPa]	85 [585]	100 [690]	70 [485]
Elongation, 2 in. [50 mm], min, %	14[A]	14[A]	16[A]

[A] See 7.1.2.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.2 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, QUENCHED AND TEMPERED 8 AND 9 PERCENT NICKEL

SA-553/SA-553M

(Identical to ASTM Specification A 553/A 553M-93.)

1. Scope

1.1 This specification covers 8 and 9% nickel alloy steel plates for use in the water quenched and tempered condition intended for the fabrication of welded pressure vessels.

1.2 Material under this specification is available in two types having different chemical composition as follows:

Type	Nominal Nickel Content, %
I	9
II	8

1.3 Plates produced under this specification are subject to impact testing at −320°F [−195°C] for Type I, and −275°F [−170°C] for Type II or at such other temperatures as are agreed upon.

1.4 The maximum thickness of plates is limited only by the capacity of the material to meet the specified mechanical property requirements; however, current mill practice normally limits this material to 2 in. [50 mm] max.

1.5 This material is susceptible to magnetization. Use of magnets in handling after heat treatment should be avoided if residual magnetism would be detrimental to subsequent fabrication or service.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information which should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 All plates shall be heat treated in accordance with 5.2. Shell plates and other parts, including heads and reinforcing pads, which are heated for forming, shall be heat treated after forming in accordance with 5.2.

5.2 *Heat Treatment Procedure* — Heat treat all plates by heating to a suitable temperature within the range from 1475 to 1700°F [800 to 925°C], holding for a sufficient time to obtain uniform temperature throughout the plate thickness and then quenching in water. Subsequently, temper the plates within the range from 1050 to 1175°F [565 to 635°C], holding at this temperature for a minimum of 30 min/in. [1.2 min/mm] of thickness but not less than 15 min, and cool in air or water quench at a rate not less than 300°F/h [165°C/h].

5.2.1 *Hardening* — The plates shall be heated to a temperature within the range from 1475 to 1700°F [800 to 925°C], held at that temperature for a sufficient time to obtain uniform temperature throughout the plate thickness, and then quenched in a liquid media.

5.2.2 *Tempering* — The plates shall be tempered at a temperature within the range from 1050 to 1175°F [565 to 635°C], being held at that temperature for a minimum of 30 min/in. [1.2 min/mm] of thickness, but in no case less than 15 min., and then cooled in air or liquid-quenched at a rate not less than 300°F/h [165°C/h].

5.2.2.1 Prior to the tempering treatment, the plates may be subjected to an intermediate heat treatment consisting of heating to a temperature in the range from 1165 to 1290°F [630 to 700°C] for Type I, or 1185 to 1310°F [640 to 710°C] for Type II, holding at that temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness, but in no case less than 15 min, and then water-quenching to below 300°F [150°C] in the case of plate thicknesses of more than $\frac{5}{8}$ in. [16 mm] or cooling in air or water-quenching to below 300°F [150°C] in the case of plate thicknesses of $\frac{5}{8}$ in. [16 mm] and under.

NOTE — The intermediate heat treatment is for the purpose of enhancing elongation and notch-toughness and for reducing susceptibility to strain-aging embrittlement and temper embrittlement. It may be performed at the option of the material manufacturer or may be specified by the purchaser.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements* — The material as represented by tension-test specimens shall conform to the requirements specified in Table 2.

7.1.1 Upon agreement between the purchaser and the manufacturer, yield strength may be determined by the extension under load method, using 0.005 in./in. [mm/mm] total extension.

7.1.2 For nominal plate thicknesses of $\frac{3}{4}$ in. [20 mm] and under, the $1\frac{1}{2}$ in. [40 mm] wide rectangular specimen may be used for the tension test and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and shows the greatest elongation.

7.2 *Impact Test Requirements:*

7.2.1 Charpy V-notch impact tests shall be made in accordance with Specification A 20/A 20M.

7.2.2 The longitudinal axis of the test specimens shall be transverse to the final rolling direction of the plate.

7.2.3 Unless otherwise agreed, tests shall be conducted at −320°F [−195°C] for Type I and at −275°F [−170°C] for Type II.

7.2.4 Each test specimen shall have a lateral expansion opposite the notch of not less than 0.015 in. [0.381 mm].

8. Finish

8.1 Because retained scale may mask surface imperfections, as well as mar the plate surface, plates shall be descaled by the producer after heat treatment. In the case of material to be heat-treated by the purchaser, the plates shall be descaled by the producer prior to shipment.

9. Marking

9.1 In addition to the marking required in Specification A 20/A 20M, each plate shall be legibly stamped or stenciled, depending upon the ordered thickness, with the letters *QT*, except as otherwise specified in 9.1.1.

9.1.1 When the optional heat treatment in 5.2.2.1 is performed, the plates shall be marked with the letters *QTT* instead of *QT*.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %	
	Type I	Type II
Carbon, max[A]	0.13	0.13
Manganese, max:		
Heat analysis	0.90	0.90
Product analysis	0.98	0.98
Phosphorus, max[A]	0.035	0.035
Sulfur, max[A]	0.035	0.035
Silicon:		
Heat analysis	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45
Nickel:		
Heat analysis	8.50–9.50	7.50–8.50
Product analysis	8.40–9.60	7.40–8.60

[A] Applies to both heat and product analyses.

TABLE 2
TENSILE REQUIREMENTS

Tensile strength, ksi [MPa]	100 to 120 [690–825]
Yield strength (0.2% offset), ksi [MPa]	85 [585]
Elongation in 2 in. [50 mm], min, %	20.0

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standard supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S6. Drop Weight Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below are additional optional Supplementary Requirements S55 and S56 which are suitable for this specification.

S55. Longitudinal Charpy Impact Energy Absorption Requirement

S55.1 The longitudinal Charpy V-notch impact properties shall not be less than 25 ft·lbf [34 J] at the specified temperature.

S55.2 Each impact test value shall constitute the average value of three specimens, with not more than one value below the specified minimum value of 25 ft·lbf [34 J] but in no case below 20 ft·lbf [27 J] for full size specimens.

S56. Transverse Charpy Impact Energy Absorption Requirement

S56.1 The transverse Charpy V-notch impact properties shall not be less than 20 ft·lbf [27 J] at the specified temperature.

S56.2 Each impact test value shall constitute the average value of three specimens, with not more than one value below the specified minimum value of 20 ft·lbf [27 J] but in no case below 15 ft·lbf [20 J] for full size specimens.

SPECIFICATION FOR SEAMLESS COLD-DRAWN CARBON STEEL FEEDWATER HEATER TUBES

SA-556/SA-556M

(Identical with ASTM Specification A 556/A 556M-90a (Reapproved 1995)$^{\epsilon 1}$.)

1. Scope

1.1 This specification covers minimum-wall-thickness, seamless cold-drawn carbon steel tubes including bending into the form of U-tubes, if specified, for use in tubular feedwater heaters.

1.2 The tubing sizes covered shall be $\frac{5}{8}$ to $1\frac{1}{4}$ in. [15.9 to 31.8 mm] outside diameter, inclusive, with minimum wall thicknesses equal to or greater than 0.045 in. [1.1 mm].

1.3 Optional supplementary requirements are provided, and when desired, shall be stated in the order.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron

3. General Requirements

3.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of the Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following as required to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of pieces),

4.1.2 Name of material (seamless steel tubing),

4.1.3 Dimensions (outside diameter and minimum wall thickness),

4.1.4 Length (specific or random),

4.1.5 Manufacture (cold drawn),

4.1.6 Grade (chemical composition),

4.1.7 Optional requirements,

4.1.8 *Bending Requirements* — If order specifies tubes to be bent, the design of the U-tubes shall accompany the order. Purchaser must specify if stress-relief anneal of the U-bends is required,

4.1.9 Test report required (see Certification Section of Specification A 450/A 450M),

4.1.10 Specification number, and

4.1.11 Special requirements and any supplementary requirements selected.

5. Manufacture

5.1 *Manufacture* — Tubes shall be made by the seamless process and shall be cold drawn.

5.2 *Heat Treatment:*

5.2.1 Cold-drawn tubes shall be heat treated after the final cold-draw pass at a temperature of 1200°F [640°C] or higher to ensure ductility satisfactory for rolling into tube sheets and to meet mechanical properties as specified.

5.2.2 If stress-relief anneal of the U-bends is specified, the anneal shall consist of heating the bent portion within a range of 1100 to 1200°F [585 to 640°C].

6. Chemical Composition

6.1 The steel shall conform to one of the requirements as to chemical composition as prescribed in Table 1.

6.2 When a grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted.

7. Product Analysis

7.1 When requested in the purchase order, a product analysis shall be made by the manufacturer or supplier from one tube or billet per heat.

7.2 If the original test for product analysis fails, retests of two additional tubes or billets shall be made. Both retests for the elements in question shall meet the requirements of this specification; otherwise, all remaining material in the heat or lot (Note) shall be rejected or, at the option of the producer, each tube may be individually tested for acceptance. Tubes that do not meet the requirements of this specification shall be rejected.

NOTE — For tension and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat and furnace speed.

7.3 For referee purposes, Test Methods E 30 shall be used.

8. Mechanical Properties

8.1 *Tensile Properties* — The material shall conform to the requirements as to tensile properties prescribed in Table 2, when pulled in full section.

8.2 *Hardness Requirements* — The tubes shall not exceed the Rockwell Hardness shown in Table 3.

9. Permissible Variations in Dimensions (Fig. 1)

9.1 Permissible variations from the specified outside diameter shall not exceed ±0.004 in. [0.10 mm] for tubing under 1.0 in. [25.4 mm] outside diameter nor ±0.006 in. [0.15 mm] for tubing 1.0 in. [25.4 mm] to 1.25 in. [31.7 mm] inclusive. These tolerances do not apply to the bent portion of the U-tubes. At the bent portion of a U-tube for $R = 2 \times D$ or greater neither the major nor minor diameter of tube shall deviate from nominal by more than 10%. If $1\frac{1}{2}$ D is specified, tolerances could be greater.

9.2 Permissible variations from the specified minimum wall thickness shall not exceed +20% or −0. The wall thickness of the tube in U-bent section shall be not less than value determined by:

$$t_f = T(2R)/(2R + D)$$

where:

t_f = wall thickness after bending, in. [mm],
T = specified minimum tube wall thickness, in. [mm],
R = centerline bend radius, in. [mm], and
D = nominal outside tube diameter, in. [mm].

9.3 In the case of U-tubes, the length of the tube legs as measured from the point of tangency of the bend and the tube leg to the end of the tube leg shall not be less than specified, but may exceed the specified values by the amount given in Table 4. The difference in lengths of the tube legs shall not be greater than $\frac{1}{8}$ in. [3 mm] unless otherwise specified.

9.4 The end of any tube may depart from square by not more than the amount given in Table 5.

9.5 The leg spacing measured between the points of tangency of the bend to the legs shall not vary from the value (2R — specified tube OD) by more than $\frac{1}{16}$ in. [1.5 mm] where R is the centerline bend radius.

9.6 The bent portion of the U-tube shall be substantially uniform in curvature and not exceed $\pm\frac{1}{16}$ in. [±1.5 mm] of the normal centerline radius.

10. Workmanship, Finish, and Appearance

10.1 Finished tubes shall be free from scale but may have a superficial oxide film on the surfaces. A light oxide scale on the outside and inside surfaces of U-bend shall be allowed for tubes which have been heat treated.

10.2 Finished tubes shall be reasonably straight and have smooth ends free from burrs. Tubes shall have a workmanlike finish and shall be free of surface imperfections that cannot be removed within the allowable wall tolerances. Removal of surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be required provided they are within the allowable wall tolerances.

10.3 Finished tubes shall be coated both on the outside and the inside diameter to prevent corrosion in transit. The type of coating applied should be mutually agreed upon and specified in the order.

11. Mechanical Tests Required

11.1 *Tension Test* — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note).

11.2 *Flattening Test* — One flattening test shall be made on specimens taken from each end of one finished tube, not the one used for the flaring test, from each lot of not more than 125 tubes or fraction thereof.

11.3 *Flaring Test* — One flaring test shall be made on specimens taken from each end of one finished tube, not the one used for flattening test, from each lot of not more than 125 tubes or fraction thereof.

11.4 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note).

11.5 *Hydrostatic Test* — Each U-tube shall be subjected to a hydrostatic test, using a noncorrosive fluid, or when agreed upon between the purchaser and manufacturer, they may be tested at $1\frac{1}{2}$ times the specified design working pressure.

12. Nondestructive Test (Electric Test)

12.1 Each tube shall be tested after the finish heat treatment following the final cold-drawn pass by passing through a nondestructive tester capable of detecting defects on the entire cross section of the tube, in accordance with Specification A 450/A 450M.

13. Packaging and Package Marking

13.1 The tubing shall be packaged or bundled in such a manner as to prevent damage in ordinary handling and transportation and identified by a tag with the name of the manufacturer, purchase order number, specification number and grade, and size.

13.2 In the case of U-tubes, each box shall be palletized and legibly marked showing the manufacturer's name, purchase order number, specification number and grade, size, and identification of items contained.

14. Keywords

14.1 feedwater heater tubes; seamless steel tube; steel tube, carbon

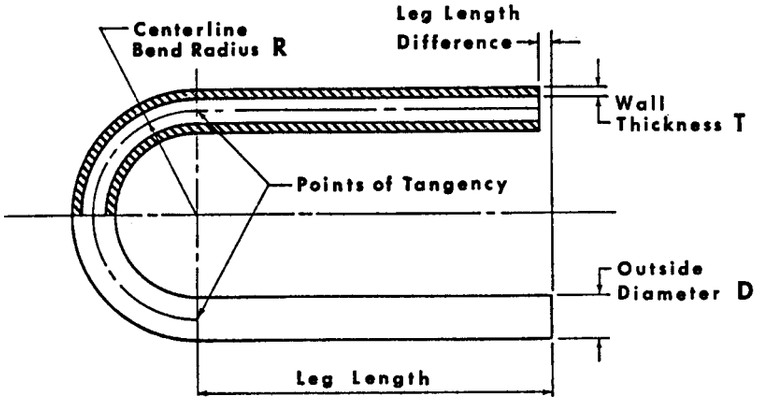


FIG. 1 BENT PORTION OF U-TUBE

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A2	Grade B2	Grade C2
Carbon, max	0.18	0.27	0.30
Manganese	0.27–0.63	0.29–0.93	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	. . .	0.10	0.10

TABLE 2
TENSILE REQUIREMENTS

	Grade A2	Grade B2	Grade C2
Tensile strength, min, ksi [MPa]	47 [320]	60 [410]	70 [480]
Yield strength, min, ksi [MPa]	26 [180]	37 [260]	40 [280]
Elongation in 2 in. or 50 mm, min, % (longitudinal)	35	30	30

TABLE 3
HARDNESS REQUIREMENTS

Grade A2	HR B72
Grade B2	HR B79
Grade C2	HR B89

TABLE 4
TUBE LEG LENGTH TOLERANCE

Leg Length, ft [mm]	Plus Tolerance in. [mm]
Up to 20 [6], incl	1/8 [3.2]
Over 20 to 30 [6 to 9], incl	5/32 [4.0]
Over 30 to 40 [9 to 12.2], incl	3/16 [4.8]

TABLE 5
SQUARENESS OF ENDS TOLERANCE

Tube OD, in. [mm]	Tolerance, in. [mm]
5/8 [15.9]	0.010 [0.25]
Over 5/8 to 1 1/4 [15.9 to 31.7], incl	0.016 [0.4]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement or requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order, in which event the necessary tests shall be made by the manufacturer prior to the bending or shipment of the tubing.

S1. Nondestructive Ultrasonic Test — Round Tubing (Commercial Grade)

S1.1 The manufacturer shall test the tubing by an ultrasonic nondestructive test for detection of harmful faults and soundness.

S1.1.1 Ultrasonic testing shall be performed using pulse-echo shear wave techniques to locate longitudinal or circumferential defects, or both.

S1.1.2 Tubes being tested shall be reasonably straight for proper rotation. The outside and inside diameter surfaces of the tubes shall be free of dirt, grit, grease, oil, loose scale, or other materials which tend to attenuate, scatter, or reflect ultrasonic signals.

S1.1.3 Tubing shall be inspected by feeding spirally past a suitable transducer with rotation of material to be toward the transducer.

S1.1.4 Suitable ultrasonic instrumentation shall be used to clearly distinguish the artificial defects (hereafter called reference notches) described later. Automatic electronic monitoring of the reflected ultrasonic signals shall be provided in such manner that any naturally occurring defects which present an ultrasonic reflection equal to or greater than the reference standard(s) shall trigger audible and visible alarms.

S1.1.5 Instrument calibration as described herein shall be accomplished with the reference standard being rotated and fed past the transducer at the same approximate rate at which the tubing under test will be tested.

S1.1.6 The following factors will be adjusted so as to achieve optimum instrument distinction between the reference notch(es) and plain portion of tubing when calibrating equipment to the reference standard.

S1.1.6.1 Search unit position shall be such that shear waves are propagated within the tube being tested. If both outside and inside diameter reference notches are used, the optimum angle shall be used which will indicate both notches as close to equal size as possible.

S1.1.6.2 The test frequency to be used shall be chosen to yield the best distinction between reference notches and plain areas of tubing. In general, 2.25 or 5.0 MHz will be used.

S1.1.6.3 Instrument sensitivity shall be adjusted to allow reference notch or notches to present a pip or pips on the scope screen at 50% to 70% of instrument saturation level. The Automatic Defect Monitoring System shall be adjusted to monitor by means of electronic gates, the portion of the screen where the reference notch is presented. The sensitivity of the alarm system shall be adjusted to indicate audibly and visibly when the reference notch is fed past the search unit.

S1.1.6.4 The recording equipment, if agreed upon, shall be adjusted to clearly indicate the reference notch or notches and also whether or not any reflected signals actuate the alarm system.

S1.1.7 A reference standard of an appropriate length (sufficient to allow in-line feeding) shall be prepared from a randomly selected tube of the same size, grade, and physical condition as the material to be tested.

S1.1.8 The reference standard shall contain machined notches as follows:

Notch to be 10% of wall thickness in depth but not less than 0.004 in. [0.10 mm]. Tolerance on depth +0.0000 in. or −0.001 in. [0.03 mm].

S1.1.8.1 *Notch Locations and Orientation* — Notches shall be located on outside or inside diameter, or both, and shall be oriented to lie in a longitudinal direction for radial inspection or circumferentially, or both, for transverse inspection. The notch or notches shall be located in the reference tube in such a manner that no physical or acoustical interference exists between notches or end of reference tube. These various locations and orientations will be classified as follows:

Type A — Longitudinal outside diameter for radial inspection,

Type B — Longitudinal inside diameter for radial inspection,
Type C — Circumferential outside diameter for transverse inspection, and
Type D — Circumferential inside diameter for transverse inspection.

S1.1.8.2 *Standard Nomenclature* — The size, location and orientation of the reference notches which become a part of a particular order covered under this specification shall be specified.

S1.1.9 The basic procedure will be to rotary feed all the tubes in the order past the search unit (transducer) with the feed helix less than the scanning width of the search unit. As the tubes are fed past the transducer, the alarm system shall be observed for indications of defects equal to or greater than the reference standard. Tubes which show such indications shall be rejected.

S1.1.10 Standard procedure will be to test the material in one direction of helical feed only. Testing in both directions may be done if so specified by customer.

S1.1.11 Any tubes that do not show indications above the level determined by the reference standard shall be held in a lot until the reference standard is run and instrument calibration is proved by triggering alarm system on the reference notch or notches. After calibration is proved to have been correct, this lot of tubes shall be considered tested and accepted as to maximum defect size corresponding to the reference standard used.

S1.1.12 Rejected tubing may be salvaged by polishing or other suitable means when practical and retested after the elimination of the cause of rejection. Such material that meets the dimensional requirements and does not cause triggering of ultrasonic alarm system upon retesting shall be considered as having met the requirements of this supplement.

S2. Nondestructive Ultrasonic Test — Round Tubing (Select Commercial Grade)

S2.1 The manufacturer shall test the tubing using the procedure outlined in Supplementary Requirement S1, except for the notch depth, which shall be 5% of wall thickness in depth but not less than 0.004 in. [0.10 mm]. Tolerance on depth shall be +0.000 in. or −0.0005 in. [0.01 mm].

S3. Nondestructive Eddy-Current Test

S3.1 Each tube shall be tested after the finish heat treatment following the final cold-draw pass by passing through an electric nondestructive tester capable of detecting defects on the entire cross section of the tube. Suitable instrumentation shall be used to clearly distinguish artificial defects or reference notches. Tubes to be tested shall be reasonably straight and the outside and inside diameter surfaces shall be free of loose scale, metallic particles, or other material which would tend to restrict signals or create electrical noise. The tubing shall be inspected by feeding longitudinally through an inspection coil or coils of a diameter suitable for the diameter of tubing to be inspected. The instrument calibration shall be accomplished with a reference standard prepared from an appropriate length of selected tubing of the same size, grade, and physical condition as the material to be inspected. The standard shall be fed through the coil at the same speed at which the inspection of the tubing is performed. The following factors shall be selected or adjusted, or both, in accordance with the instrument manufacturer's instructions for the particular instrument involved as required to achieve optimum instrument distinction between the reference defects and plain portion of the tube. These as well as other factors involved shall not be used in such a manner that they detract from the instrument's overall ability to detect injurious defects:

S3.1.1 Test frequency;

S3.1.2 Direct-current saturation level,

S3.1.3 Filter networks,

S3.1.4 Phase analysis circuits,

S3.1.5 Coil diameter, and

S3.1.6 Instrument gain.

S3.2 The reference standard shall contain longitudinal and circumferential notches in the outside diameter and shall be used to establish the rejection level for the tubing to be tested. Inside diameter notches, both longitudinal and circumferential, shall also be a part of the reference standard. These notches may be larger than outside diameter notches and are intended for use only to assure instrument phase settings capable of yielding optimum inside diameter surface sensitivity. The outside diameter reference notches shall have a depth equal to 10% of the wall thickness. The tolerance of the notch shall be ±8% or 0.0005 in. [0.01 mm], whichever is the greater. Width of notch shall not exceed twice the depth. The length of the reference notches shall not exceed 0.375 in. [9.5 mm]. All tubing including that

which may be reconditioned, provided the dimensional or other properties of the tubing are not adversely affected and provided the tubing does not show indications above the level determined by the outside diameter references, shall meet this specification provided the instrument calibration is verified by indicating the standard outside diameter reference notches of a given lot. Tubes generating a signal above the calibration standard sensitivity level shall be rejected. Tubes may be reconditioned if not adversely affecting the dimensional or other properties of the tube and so tested as to assure a satisfactory tube within the limits of this specification. All tubing shall be demagnetized after inspection has been completed.

SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED CARBON STEEL FEEDWATER HEATER TUBES

SA-557/SA-557M

(Identical with ASTM Specification A 557/A 557M-90a.)

1. Scope

1.1 This specification covers minimum-wall-thickness, electric-resistance-welded, carbon steel tubes including those bent, if specified, into the form of U-tubes for application in tubular feedwater heaters.

1.2 The tubing sizes covered shall be $\frac{1}{8}$ to $1\frac{1}{4}$ in. [15.9 to 31.8 mm] outside diameter, inclusive, and wall thicknesses equal to or greater than 0.045 in. [1.1 mm].

1.3 Optional supplementary requirements are provided and, when desired, shall be stated in the order.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

E 30 Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron

3. General Requirements

3.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material to this specification should include the following as required to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of pieces),

4.1.2 Name of material (electric-resistance-welded steel tubing),

4.1.3 Dimensions (outside diameter and minimum wall thickness),

4.1.4 Length (specific or random),

4.1.5 Manufacture (hot rolled or cold drawn; cold-rolled strip may be used as an alternate to hot-rolled strip),

4.1.6 Grade (Section 7) Table 1,

4.1.7 *Optional requirements* — If order specifies bending, a drawing of the U-tubes shall accompany the order. Purchaser must specify if stress-relief anneal of the U-bends is required (Product analysis, Section 8),

4.1.8 Test Report required (see Certification Section of Specification A 450/A 450M),

4.1.9 Specification designation, and

4.1.10 Special requirements and any supplementary requirements selected.

5. Manufacture

5.1 *Manufacture* — Tubes shall be made by electric-resistance welding.

5.2 *Heat Treatment:*

5.2.1 Following welding, tubes shall be normalized at a temperature of at least 1600°F [860°C] followed by cooling in air or cooling in the cooling zone of continuous atmosphere controlled furnace.

5.2.2 If cold drawn, tubes shall be heated after the final cold-working operation to a temperature of at least 1200°F [640°C] to ensure ductility satisfactory for rolling into tube sheets and to meet the specified mechanical properties.

5.2.3 If heat treatment of the U-bends is specified, such heat treatment shall consist of heating the stressed portion within a range from 1100 to 1200°F [590 to 640°C].

6. Surface Condition

6.1 Finished tubes shall be free of scale but may have a superficial oxide film on the surfaces. A light-oxide scale on the outside and inside surfaces of U-bend shall be allowed for tubes which have been heat treated for relief of stress.

6.2 Finished tubes shall be coated on both outside and inside diameter with a thin paraffin oil to prevent corrosion in transit. Other types of coatings may be applied as mutually agreed upon and specified in the order.

7. Chemical Composition

7.1 The steel shall conform to one of the requirements as to chemical composition as prescribed in Table 1.

7.2 For all tubes, the steel shall be fully killed.

7.3 When a grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 is not permitted.

8. Product Analysis

8.1 When requested in the purchase order, a product analysis shall be made by the supplier from one tube or coil of steel per heat.

8.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes, shall be made. Both retests, for the elements in question shall meet the requirements of this specification; otherwise all remaining material in the heat shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of this specification shall be rejected.

8.3 For referee purposes, Methods E 30 shall be used.

9. Mechanical Requirements

9.1 *Tensile Properties* — The material shall conform to the requirements as to tensile properties prescribed in Table 2.

9.2 *Hardness Requirements* — The tubes shall not exceed the Rockwell Hardness shown in Table 3.

10. Permissible Variations in Dimensions

10.1 Permissible variations from the specified outside diameter shall be in accordance with the applicable portions of Specification A 450/A 450M. The height of flash on the inside of hot-rolled tubes shall be as specified in Specification A 450/A 450M. Cold-drawn tubes shall have no dimensional indication of welding flash. Tolerances for diameter and wall thickness do not apply to the bent portion of U-tubes. At the bent portion of a U-tube, for $R = 2 \times D$, neither the major nor minor diameter of the tube shall deviate from nominal by more than 10%.

10.2 Permissible variations from the specified minimum wall thickness shall not exceed + 18% − 0 for the straight tubing. The wall thickness of the U-tube in the bent section shall be not less than the value determined by:

$$t_f = T(2R)/(2R + D)$$

where:

t_f = wall thickness after bending, in. [mm],
T = specified minimum tube wall thickness, in. [mm],

R = centerline bend radius, in. [mm], and
D = nominal outside tube diameter, in. [mm].

10.3 Permissible variations from the specified straight length shall be in accordance with Specification A 450/A 450M.

10.4 In the case of U-tubes, the length of the tube legs, as measured from the point of tangency of the bend and the tube leg to the end of the tube leg, shall not be less than specified, but may exceed the specified values by the amount given in Table 4. The difference in lengths of the tube legs shall not be greater than $\frac{1}{8}$ in. [3 mm] unless otherwise specified.

10.5 The end of any tube may depart from the square by not more than the amount given in Table 5.

10.6 The leg spacing measured between the points of tangency of the bend to the legs shall not vary from the value (2*R*-specified tube OD) by more than $\frac{1}{16}$ in. [1.5 mm] where *R* is the centerline bend radius.

10.7 The bent portion of the U-tube shall be substantially uniform in curvature and not exceed $\pm\frac{1}{16}$ in. [$\pm$1.5 mm] of the normal centerline radius.

11. Mechanical Tests Required

11.1 *Tension Test* — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 2).

NOTE 1 — For flattening and flange requirements, a lot consists of the 125 tubes.

NOTE 2 — For tension and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat and furnace speed.

11.2 *Flattening Test* — One flattening test as specified in Specification A 450/A 450M shall be made on a specimen taken from one tube from each lot (Note 1) or fraction thereof.

11.3 *Flange Test* — One flange test as specified in Specification A 450/A 450M shall be made on a specimen from one tube from each lot (Note 2) or fraction thereof. For Grades B and C, the width of the flange shall not be less than 75% of that specified in Specification A 450/A 450M.

11.4 *Reverse Flattening Test* — One reverse flattening test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

11.5 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 2). Method of testing and restrictions on wall thickness shall be in accordance with Specification A 450/A 450M.

11.6 *Hydrostatic Test* — Each U-tube shall be subjected to a hydrostatic test, using a noncorrosive fluid, or when agreed upon by the purchaser and manufacturer, they may be tested to $1\frac{1}{2}$ times the specified design pressure.

11.7 Methods of mechanical testing, test specimens, retests and retreatment shall be in accordance with Specification A 450/A 450M.

12. Nondestructive Test (Electric Test)

12.1 Each tube shall be tested after the final heat treatment in accordance with the requirements of the nondestructive electric test in Specification A 450/A 450M.

13. Product Marking

13.1 Marking shall be in accordance with Specification A 450/A 450M. Symbols stamped or rolled into the tube surface are not permissible.

14. Packaging

14.1 The manufacturer at his option will box, crate, carton, or package in secured lifts, or bundle to ensure safe delivery. Special packaging requiring extra operations other than those normally used by the manufacturer must be specified on the order.

14.2 In case of U-tubes, each box shall be palletized and legibly marked with purchase order number, specification number, size, name of manufacturer, and identification of items contained.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A2	Grade B2	Grade C2
Carbon, max	0.18	0.30	0.35
Manganese	0.27–0.63	0.27–0.93	0.27–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035

TABLE 2
TENSILE REQUIREMENTS

	Grade A2	Grade B2	Grade C2
Tensile strength, min, ksi [MPa]	47 [325]	60 [415]	70 [485]
Yield strength, min, ksi [MPa]	26 [180]	37 [255]	40 [275]
Elongation in 2 in. or 50 mm, min, % (longitudinal)	35	30	30

TABLE 3
HARDNESS REQUIREMENTS

Grade A	HRB 72
Grade B	HRB 79
Grade C	HRB 89

TABLE 4
TUBE LEG LENGTH TOLERANCE

Leg Length, ft [m]	Plus Tolerance, in. [mm]
Up to 20 [6], incl	1/8 [3.2]
Over 20 to 30 [6 to 9], incl	5/32 [4.0]
Over 30 to 40 [9 to 12.2], incl	3/16 [4.8]

TABLE 5
SQUARENESS OF ENDS TOLERANCE

Tube OD, in. [mm]	Tolerance in. [mm]
5/8 [15.9]	0.010 [0.25]
Over 5/8 to 1 1/4 [15.9 to 31.7], incl	0.016 [0.4]

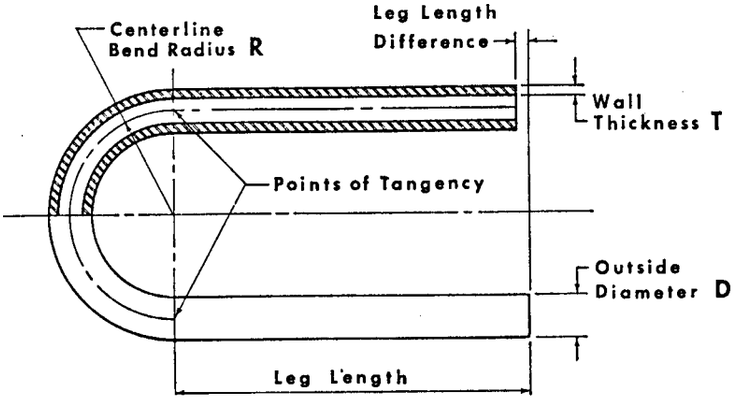


FIG. 1 BENT PORTION OF U-TUBE

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement or requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered unless specified in the order, in which event the necessary tests shall be made by the manufacturer prior to the bending or shipment of the tubing.

S1. Nondestructive Ultrasonic Test-Round Tubing (Commercial Grade)

S1.1 The manufacturer shall test the tubing by an ultrasonic nondestructive test for detection of harmful faults.

S1.1.1 Ultrasonic testing shall be performed using pulse-echo shear-wave techniques to locate longitudinal or circumferential defects, or both.

S1.1.2 Tubes being tested shall be reasonably straight for proper rotation. The outside and inside diameter surfaces of the tubes shall be free of dirt, grit, grease, oil, loose scale, or other materials which tend to attenuate, scatter, or reflect ultrasonic signals.

S1.1.3 Tubing shall be inspected by feeding spirally past a suitable transducer with rotation of material to be toward transducer.

S1.1.4 Suitable ultrasonic instrumentation shall be used to clearly distinguish the artificial defects (hereafter called "reference notches") described later. Automatic electronic monitoring of the reflected ultrasonic signals shall be provided in such manner that any naturally occurring defects which present an ultrasonic reflection equal to or greater than the reference standard(s) shall trigger audible and visible alarms.

S1.1.5 Instrument calibration as described herein shall be accomplished with the reference standard being rotated and fed past the transducer at the same approximate rate as the tubing to be tested.

S1.1.6 The following factors shall be adjusted so as to achieve optimum instrument distinction between the reference notch(es) and plain portion of tubing when calibrating equipment to the reference standard.

S1.1.6.1 Search unit position shall be such that shear waves are propagated within the tube being tested. If both outside and inside diameter reference notches are used, the optimum angle shall be used which will indicate both notches as close to equal size as possible.

S1.1.6.2 The test frequency to be used shall be chosen to yield the best distinction between reference notches and plain areas of tubing. In general, 2.25 or 5.0 MH will be used.

S1.1.6.3 Instrument sensitivity shall be adjusted to allow reference notch or notches to present a pip or pips on the scope screen at 50 to 70% of instrument saturation level. The automatic defect monitoring system shall be adjusted to monitor, by means of electronic gates, the portion of the screen where the reference notch is presented. The sensitivity of the alarm system shall be adjusted to indicate audibly and visibly when the reference notch is fed past the search unit.

S1.1.6.4 The recording equipment, if agreed upon, shall be adjusted to clearly indicate the reference notch or notches and also whether or not any reflected signals actuate the alarm system.

S1.1.7 A reference standard of an appropriate length (sufficient to allow in-line feeding) shall be prepared from a randomly selected tube of the same size, grade, and physical condition as the material to be tested.

S1.1.8 The reference standard shall contain machined notches as follows: Notch to be 10% of wall thickness in depth but not less than 0.004 in. [0.10 mm]. Tolerance on depth shall be +0.0000 or −0.001 in. [0.03 mm].

S1.1.8.1 *Notch Locations and Orientation* — Notches shall be located on outside or inside diameter, or both, and shall be oriented to lie in a longitudinal direction for "radial" inspection or circumferentially for "transverse" inspection, or both. The notch or notches shall be located in the reference tube in such a manner that no physical or acoustical interference exists between notches or end of reference tube. These various locations and orientations will be classified as follows:

Type A — Longitudinal outside diameter for radial inspection,

Type B — Longitudinal inside diameter for radial inspection,
Type C — Circumferential outside diameter for transverse inspection, and
Type D — Circumferential inside diameter for transverse inspection.

S1.1.8.2 *Standard Nomenclature* — The size, location, and orientation of the reference notches which become a part of a particular order covered under this specification shall be specified.

S1.1.9 The basic procedure will be to rotary feed all the tubes on the order past the search unit (transducer) with the feed helix less than the scanning width of the search unit. As the tubes are fed past the transducer, the alarm system shall be observed for indications of defects equal to or greater than the reference standard. Tubes that show such indication shall be rejected.

S1.1.10 Standard procedure will be to test the material in one direction of helical feed only. Testing in both directions may be done if so specified by customer.

S1.1.11 Any tubes that do not show indications above the level determined by the reference standard shall be held in a lot until the reference standard is run and instrument calibration is proved by triggering the alarm system on the reference notch or notches. After calibration is proved to have been correct, this lot of tubes shall be considered tested and accepted as to maximum defect size corresponding to the reference standard used.

S1.1.12 Rejected tubing may be salvaged by polishing or other suitable means when practical and retested after the elimination of the cause of rejection. Such material that meets the dimensional requirements and does not cause triggering of the ultrasonic alarm system upon retesting shall be considered as having met the requirements of this supplement.

S2. Nondestructive Ultrasonic Test-Round Tubing (Select Commercial Grade)

S2.1 The manufacturer shall test the tubing using the procedure outlined in Supplementary Requirement S1, except for the notch depth. The notch shall be 5% of wall thickness in depth but not less than 0.004 in. [0.10 mm]. Tolerance on depth shall be +0.000, −0.005 in. [0.01 mm].

S3. Nondestructive Test (Eddy-Current Test)

S3.1 Each tube shall be tested after the finish heat treatment by passing through an electric nondestructive tester capable of detecting defects on the entire cross section of the tube. Suitable instrumentation shall be used to clearly distinguish artificial defects or reference notches. Tubes to be tested shall be reasonably straight and the outside and inside diameter surfaces shall be free of loose scale, metallic particles, or other material which would tend to restrict signals or create electrical noise. The tubing shall be inspected by feeding longitudinally through an inspection coil of a diameter suitable for the diameter of tubing to be inspected. The instrument calibration shall be accomplished with a reference standard prepared from an appropriate length of selected tubing of the same size, grade, and physical condition as the material to be inspected. The standard shall be fed through the coil at the same speed at which the inspection of the tubing is performed.

S3.1.1 The following factors will be selected or adjusted, or both, in accordance with the instrument manufacturer's instructions for the particular instrument involved as required to achieve optimum instrument distinction between the reference defects and plain portion of the tube. These as well as other factors involved shall not be used in such a manner that they detract from the instrument's overall ability to detect injurious defects:

S3.1.1.1 Test frequency,

S3.1.1.2 Direct-current saturation level,

S3.1.1.3 Filter networks,

S3.1.1.4 Phase analysis circuits,

S3.1.1.5 Coil diameter, and

S3.1.1.6 Instrument gain.

S3.1.2 The reference standard shall contain longitudinal and circumferential notches in the outside diameter and shall be used to establish rejection level for the tubing to be tested. Inside diameter notches, both longitudinal and circumferential, shall also be a part of the reference standard. These notches may be larger than outside diameter notches and are intended for use only to assure instrument phase settings capable of yielding optimum inside diameter surface sensitivity. The outside diameter reference notches shall have a depth equal to 10% of the wall thickness. The tolerance of the notch shall be ±8% or 0.0005 in. [0.01 mm], whichever is the greater. Width of notch shall not exceed twice the

depth. The length of the reference notches shall not exceed 0.375 in. [9.5 mm]. All tubing including that which may be reconditioned, provided the dimensional or other properties of the tubing are not adversely affected, and provided the tubing does not show indications above the level determined by the outside diameter references, shall meet this specification. This is contingent upon the instrument calibration being verified by indicating the standard outside diameter reference notches of a given lot. Tubes generating a signal above the calibration standard sensitivity level shall be rejected. Tubes may be reconditioned if not adversely affecting the dimensional or other properties of the tube and so tested as to assure a satisfactory tube within the limits of this specification. All tubing shall be demagnetized after inspection has been completed.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, MANGANESE-TITANIUM FOR GLASS OR DIFFUSED METALLIC COATINGS

SA-562/SA-562M

(Identical with ASTM Specification A 562/A 562M-90.) 98

1. Scope

1.1 This specification covers titanium-bearing carbon steel plates intended for welded glass lined pressure vessels or other applications where the presence of free-iron carbide would be deleterious to the coating. A minimum specific ratio of titanium to carbon is specified.

1.2 The maximum thickness of plates is limited to 2 in. [50 mm].

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

98 2. Referenced Document

2.1 *ASTM Standard:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information which should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed.

5. Heat Treatment

5.1 Plates shall be thermally treated to produce grain refinement, either by normalizing or heating uniformly for hot forming at a minimum temperature of 1600°F [870°C] or some higher agreed temperature, and held at this temperature for a minimum of 1 h/in. [2.4 min/mm] of thickness.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements* — The material as represented by the tension-test specimens show conform to the requirements shown in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %
Carbon, max[A]	0.12
Manganese, max	
Heat analysis	1.20
Product analysis	1.30
Phosphorus, max[A]	0.035
Sulfur, max[A]	0.040
Silicon[A]	0.15–0.50
Copper, max[A]	0.15
Titanium, min	4 × C

[A] Applies to both heat and product analyses.

TABLE 2 98
TENSILE REQUIREMENTS

	ksi [MPa]
Tensile strength	55–75 [380–515]
Yield strength, min	30 [205]
Elongation in 8 in. [200 mm] min, %	22[A]
Elongation in 2 in. [50 mm] min, %	26

[A] See Specification A 20/A 20M.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4. Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR CARBON AND ALLOY STEEL NUTS

SA-563

(Identical with ASTM Specification A 563-94) 98

1. Scope

1.1 This specification covers chemical and mechanical requirements for eight grades of carbon and alloy steel nuts for general structural and mechanical uses on bolts, studs, and other externally threaded parts.

NOTE 1 — See Appendix X1 for guidance on suitable application of nut grades.

1.2 The requirements for any grade of nut may, at the supplier's option, and with notice to the purchaser, be fulfilled by furnishing nuts of one of the stronger grades specified herein unless such substitution is barred in the inquiry and purchase order.

1.3 Grades C3 and DH3 nuts have atmospheric corrosion resistance and weathering characteristics comparable to that of the steels covered in Specifications A 242/A 242M, A 588/A 588M, and A 709/A 709M. The atmospheric corrosion resistance of these steels is substantially better than that of carbon steel with or without copper addition (see 5.2). When properly exposed to the atmosphere, these steels can be used bare (uncoated) for many applications.

NOTE 2 — A complete metric companion to Specification A 563 has been developed — A 563M; therefore, no metric equivalents are presented in this specification.

2. Referenced Documents

98 **2.1** *ASTM Standards:*

A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service

A 242/A 242M Specification for High-Strength Low-Alloy Structural Steel

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength

A 325 Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

A 394 Specification for Steel Transmission Tower Bolts, Zinc-Coated and Bare

A 449 Specification for Quenched and Tempered Steel Bolts and Studs

A 490 Specification for Heat-Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength

A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point to 4 in. (100 mm) Thick

A 687 Specification for High-Strength Nonheaded Steel Bolts and Studs

A 709/A 709M Specification for Carbon and High-Strength Low-Alloy Structural Steel Shapes, Plates and Bars and Quenched and Tempered Alloy Structural Steel Plates for Bridges

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

D 3951 Practice for Commercial Packaging

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

F 812/F 812M Specification for Surface Discontinuities of Nuts, Inch and Metric Series
G 101 Guide for Estimating the Atmospheric Corrosion Resistance of Low Alloy Steels

2.2 *ANSI Standards:*
ANSI B1.1 Unified Screw Threads
ANSI B18.2.2 Square and Hex Nuts

3. Ordering Information

3.1 Orders for nuts under this specification shall include the following:

3.1.1 Quantity (number of nuts),

3.1.2 Nominal size and thread series of nuts,

3.1.3 Style of nut (for example, heavy hex),

3.1.4 Grade of nut,

3.1.5 *Zinc Coating* — Specify the zinc-coating process required, for example, hot-dip, mechanically deposited, or no preference (see 4.7),

3.1.6 *Other Finishes* — Specify other protective finish if required,

3.1.7 ASTM designation and year of issue, and

3.1.8 Supplementary or special requirements.

NOTE 3 — An example of an ordering description follows: 1000 $^{7}/_{8}$-9 heavy hex nuts, Grade DH, hot-dip zinc-coated, and lubricated, ASTM A 563-XX.

4. Materials and Manufacture

4.1 Steel for nuts shall be made by the open-hearth, basic-oxygen, or electric-furnace process except that steel for Grades O, A, and B nuts may be made by the acid-bessemer process.

4.2 Nuts may be made cold or hot by forming, pressing, or punching or may be machined from bar stock.

4.3 Grades DH and DH3 nuts shall be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and tempering at a temperature of at least 800°F.

4.4 Grades C and D nuts made of steel having carbon content not exceeding 0.20%, phosphorus not exceeding 0.04%, and sulfur not exceeding 0.05% by heat analysis may be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and need not be tempered. When this heat treatment is used, there shall be particular attention to the requirements in 6.1.1.

4.5 Grades C, C3 and D nuts made of any steel permitted for these grades may be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and tempering at a temperature of at least 800°F.

4.6 Threads shall be formed by tapping or machining.

4.7 *Zinc Coatings, Hot-Dip and Mechanically Deposited:*

4.7.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot-dip, mechanically deposited, or no preference.

4.7.2 When hot-dip is specified, the fasteners shall be zinc-coated by the hot-dip process in accordance with the requirements of Class C, of Specification A 153.

4.7.3 When mechanically deposited is specified, the fasteners shall be zinc coated by the mechanical deposition process in accordance with the requirements of Class 50 of Specification B 695.

4.7.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C, or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier's option is limited to one process per item with no mixed processes in a lot.

4.7.5 Hot-dip zinc-coated nuts shall be tapped after zinc coating.

4.7.6 Mechanically deposited zinc-coated nuts for assembly with mechanically deposited zinc-coated bolts shall be tapped oversize prior to zinc coating and need not be retapped afterwards.

4.8 *Lubricant:*

4.8.1 Hot-dip and mechanically deposited zinc-coated Grade DH nuts shall be provided with an additional lubricant which shall be clean and dry to the touch,

4.8.2 See Supplementary Requirement S2 for option to specify a dye in the lubricant.

5. Chemical Composition

5.1 Grades O, A, B, C, D, and DH shall conform to the chemical composition specified in Table 1.

5.2 Grades C3 and DH3 shall conform to the chemical composition specified in Table 2. See Guide G 101 for methods of estimating the atmospheric corrosion resistance of low alloy steels.

5.3 Resulfurized or rephosphorized steel, or both, are not subject to rejection based on product analysis for sulfur or phosphorus.

5.4 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted for Grades D, DH, and DH3.

5.5 Chemical analyses shall be performed in accordance with Test Methods, Practices, and Terminology A 751.

6. Mechanical Properties

6.1 *Hardness:*

6.1.1 The hardness of nuts of each grade shall not exceed the maximum hardness specified for the grade in Table 3.

6.1.2 Jam nuts, slotted nuts, nuts smaller in width across flats or thickness than standard hex nuts (7.1), and nuts that would require a proof load in excess of 160 000 lbf may be furnished on the basis of minimum hardness requirements specified for the grade in Table 3, unless proof load testing is specified in the inquiry and purchase order.

6.2 *Proof Load:*

6.2.1 Nuts of each grade, except those listed in 6.1.2, shall withstand the proof load stress specified for the grade, size, style, thread series, and surface finish of the nut in Table 3 and 4.

6.2.2 Nuts hot dip or mechanically zinc coated in accordance with 4.7.2 or 4.7.3 shall be proof load tested after zinc coating and overtapping.

7. Dimensions

7.1 Unless otherwise specified, nuts shall be plain (uncoated) and shall conform to the dimensions prescribed in ANSI B18.2.2.

7.2 Hex and hex-slotted nuts over $1\frac{1}{2}$ to 2 in. inclusive shall have dimensions conforming to ANSI B18.2.2 calculated using the formulas for the $1\frac{1}{4}$ through $1\frac{1}{2}$ in. size range in Appendix III (Formulas for Nut Dimensions) of ANSI B18.2.2.

7.3 *Threads: Plain (Uncoated) Nuts*

7.3.1 Unless otherwise specified, the threads shall conform to the dimensions for coarse threads with Class 2 B tolerances prescribed in ANSI B1.1.

7.4 *Threads: Nuts Hot Dip Zinc Coated* per A 153 C1. C (Sec. 4.7.2)

7.4.1 Nuts to be used on bolts with Class 2A threads before hot-dip zinc coating, and then hot-dip zinc coated in accordance with Specification A 153, Class C, shall be tapped oversize, after coating, to the minimum and maximum thread dimensions in Table 5. The major and minor diameters shall also be increased by the allowance to provide the corresponding minimum and maximum major and minor diameters.

7.5 *Threads: Nuts With Other Coatings*

7.5.1 Nuts to be used on bolts mechanically zinc coated or on bolts hot-dip zinc-coated to a specification other than Specification A 153, Class C, or otherwise hot-dip coated, shall be tapped oversize by a diametral amount sufficient to permit assembly on the coated bolt thread, unless other requirements are specified in the inquiry or purchase order.

7.5.2 When specifically permitted by the purchaser, nuts for bolts with electrodeposited coating, such as cadmium, zinc, and so forth, or with chemically applied coating may be tapped oversize by a diametral amount sufficient to permit assembly on the coated bolt thread.

7.5.3 The allowable oversize tapping shall not exceed that specified in Table 5.

8. Workmanship

8.1 Surface discontinuity limits shall be in accordance with Specification F 812/F 812M.

9. Number of Tests

9.1 The requirements of this specification shall be met in continuous mass production for stock, and the manufacturer shall make sample inspections to ensure that the product conforms to the specified requirements. Additional tests of individual shipments of material are not ordinarily contemplated. Individual heats of steel are not identified in the finished product.

9.2 When additional tests are specified in the inquiry and purchase order, a lot, for purposes of selecting test samples, shall consist of all material offered for inspection at one time that has the following common characteristics:

9.2.1 Grade,

9.2.2 Nominal size,

9.2.3 Style of nut,

9.2.4 Thread series and class, and

9.2.5 Surface finish.

9.3 Unless otherwise specified in the inquiry and purchase order, the number of tests for each lot of required property shall be as follows:

Number of Nuts in Lot	Number of Specimens
800 and under	1
801 to 8 000	2
8 001 to 22 000	3
Over 22 000	5

9.4 If any test specimen shows flaws, it may be discarded and another specimen substituted.

9.5 Should any specimen fail to meet the requirements of any specified test, double the number of specimens from the same lot shall be tested for this property, in which case all of the additional specimens shall meet the specifications.

10. Test Methods

10.1 Tests shall be conducted in accordance with Test Methods F 606.

11. Inspection

11.1 If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

11.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13. Product Marking

13.1 Nuts made to the requirements of Grades O, A, and B are not required to be marked unless individual marking is specified in the inquiry and order. When individual marking is required, the mark shall be the grade letter symbol on one face of the nut.

13.2 Heavy hex nuts made to the requirements of Grade C (Note 4) shall be marked on one face with three circumferential marks 120° apart.

13.3 Heavy hex nuts made to the requirements of Grade C3 shall be marked on one face with three circumferential marks 120° apart and the numeral 3. In addition, the manufacturer may add other distinguishing marks indicating that the nut is atmospheric corrosion resistant and of a weathering type.

13.4 Nuts made to the requirements of Grade D shall be marked with the grade symbol, D (Note 4) on one face.

13.5 Nuts made to the requirements of Grade DH shall be marked with the grade symbol, DH (Note 4) on one face.

13.6 Heavy hex nuts made to the requirements of Grade DH3 shall be marked with the grade symbol DH3 on one face. Hex nuts made to the requirements of DH3 shall be marked with the symbol HX3 on one face. In addition, the manufacturer may add other distinguishing marks indicating that the nut is atmospheric corrosion resistant and of a weathering type.

13.7 In addition, nuts of Grades C, C3, D, DH, and DH3 and hex nuts made to the requirements of DH3, shall be marked with a symbol to identify the manufacturer or private label distributor, as appropriate.

13.8 Marks may be raised or depressed at the option of the manufacturer. However, if markings are located on the bearing surface, they shall be depressed.

13.9 Grade and manufacturer's or private label distributor's identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

NOTE 4 — See Table 3 for marking of equivalent nuts made in accordance with requirements of Specification A 194/A 194M.

14. Packaging and Package Marking

14.1 *Packaging:*

14.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

14.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

14.2 *Package Marking:*

14.2.1 Each shipping unit shall include or be plainly marked with the following information:

14.2.1.1 ASTM designation and grade,

14.2.1.2 Size,

14.2.1.3 Name and brand or trademark of the manufacturer,

14.2.1.4 Number of pieces,

14.2.1.5 Purchase order number, and

14.2.1.6 Country of origin.

15. Report

15.1 When specified in the order, the manufacturer shall furnish a test report certified to be the last completed set of mechanical tests for each stock size in each shipment.

16. Responsibility

16.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested and inspected in accordance with the specification and meets all of its requirements.

17. Keywords

17.1 alloy steel; carbon steel; nuts; steel; weathering steel

TABLE 1
CHEMICAL REQUIREMENTS FOR GRADES 0, A, B, C, D, AND DH NUTS

Grade of Nut	Analysis	Composition, % Carbon	Manganese, min	Phosphorus, max	Sulfur, max
0, A, B, C	heat	0.55 max	. . .	0.12	0.15[A]
	product	0.58 max	. . .	0.13[B]	. . .
D[C]	heat	0.55 max	0.30	0.04	0.05
	product	0.58 max	0.27	0.048	0.058
DH[C]	heat	0.20–0.55	0.60	0.04	0.05
	product	0.18–0.58	0.57	0.048	0.058

[A] Sulfur content may be 0.23 max for Grade 0, A, and B nuts if agreed between the manufacturer and the purchaser.

[B] Acid bessemer steel only.

[C] For D and DH nuts, sulfur content may be 0.05 to 0.15% in which case manganese must be a minimum of 1.35%.

TABLE 2
CHEMICAL REQUIREMENTS FOR GRADES C3 AND DH3 NUTS

Element	Composition, %							
	Classes for Grade C3 Nuts[A]							Grade DH3 Nuts
	N	A	B	C	D	E	F	
Carbon:								
Heat analysis	. . .	0.33–0.40	0.38–0.48	0.15–0.25	0.15–0.25	0.20–0.25	0.20–0.25	0.20–0.53
Product analysis	. . .	0.31–0.42	0.36–0.50	0.14–0.26	0.14–0.26	0.18–0.27	0.19–0.26	0.19–0.55
Manganese:								
Heat analysis	. . .	0.90–1.20	0.70–0.90	0.80–1.35	0.40–1.20	0.60–1.00	0.90–1.20	0.40 min
Product analysis	. . .	0.86–1.24	0.67–0.93	0.76–1.39	0.36–1.24	0.56–1.04	0.86–1.24	0.37 min
Phosphorus:								
Heat analysis	0.07–0.15	0.040 max	0.06–0.12	0.035 max	0.040 max	0.040 max	0.040 max	0.046 max
Product analysis	0.07–0.155	0.045 max	0.06–0.125	0.040 max	0.045 max	0.045 max	0.045 max	0.052 max
Sulfur:								
Heat analysis	0.050 max	0.050 max	0.050 max	0.040 max	0.050 max	0.040 max	0.040 max	0.050 max
Product analysis	0.055 max	0.055 max	0.055 max	0.045 max	0.055 max	0.045 max	0.045 max	0.055 max
Silicon:								
Heat analysis	0.20–0.90	0.15–0.35	0.30–0.50	0.15–0.35	0.25–0.50	0.15–0.35	0.15–0.35	. . .
Product analysis	0.15–0.95	0.13–0.37	0.25–0.55	0.13–0.37	0.20–0.55	0.13–0.37	0.13–0.37	. . .
Copper:								
Heat analysis	0.25–0.55	0.25–0.45	0.20–0.40	0.20–0.50	0.30–0.50	0.30–0.60	0.20–0.40	0.20 min
Product analysis	0.22–0.58	0.22–0.48	0.17–0.43	0.17–0.53	0.27–0.53	0.27–0.63	0.17–0.43	0.17 min
Nickel:								
Heat analysis	1.00 max	0.25–0.45	0.50–0.80	0.25–0.50	0.50–0.80	0.30–0.60	0.20–0.40	0.20 min[B]
Product analysis	1.03 max	0.22–0.48	0.47–0.83	0.22–0.53	0.47–0.83	0.27–0.63	0.17–0.43	0.17 min
Chromium:								
Heat analysis	0.30–1.25	0.45–0.65	0.50–0.75	0.30–0.50	0.50–1.00	0.60–0.90	0.45–0.65	0.45 min
Product analysis	0.25–1.30	0.42–0.68	0.47–0.83	0.27–0.53	0.45–1.05	0.55–0.95	0.42–0.68	0.42 min
Vanadium:								
Heat analysis	. . .	. . .	. . .	0.020 min	. . .	. . .	. . .	. . .
product analysis	. . .	. . .	. . .	0.010 min	. . .	. . .	. . .	. . .
Molybdenum:								
Heat analysis	. . .	. . .	0.06 max	. . .	0.10 max	. . .	. . .	0.15 min[B]
Product analysis	. . .	. . .	0.07 max	. . .	0.11 max	. . .	. . .	0.14 min
Titanium:								
Heat analysis	. . .	. . .	. . .	. . .	0.05 max	. . .	. . .	. . .
Product analysis	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A] C3 nuts may be made of any of the above listed material classes. Selection of the class shall be at the option of the manufacturer.
[B] Nickel or molybdenum may be used.

TABLE 3
MECHANICAL REQUIREMENTS
Nuts with UNC, 8 UN, 6 UN and Coarser Pitch Threads

Grade of Nut	Nominal Nut Size, in.	Style of Nut	Proof Load stress, ksi[A]		Hardness			
					Brinell		Rockwell	
			Non-Zinc-Coated Nuts[B]	Zinc-Coated Nuts[B]	min	max	min	max
0	1/4 to 1 1/2	square	69	52	103	302	B55	C32
A	1/4 to 1 1/2	square	90	68	116	302	B68	C32
0	1/4 to 1 1/2	hex	69	52	103	302	B55	C32
A	1/4 to 1 1/2	hex	90	68	116	302	B68	C32
B	1/4 to 1	hex	120	90	121	302	B69	C32
B	1 1/8 to 1 1/2	hex	105	79	121	302	B69	C32
D[C]	1/4 to 1 1/2	hex	135	135	159	352	B84	C38
DH[D]	1/4 to 1 1/2	hex	150	150	248	352	C24	C38
DH3	1/2 to 1	hex	150	150	248	352	C24	C38
A	1/4 to 4	heavy hex	100	75	116	302	B68	C32
B	1/4 to 1	heavy hex	133	100	121	302	B69	C32
B	1 1/8 to 1 1/2	heavy hex	116	87	121	302	B69	C32
C[C]	1/4 to 4	heavy hex	144	144	143	352	B78	C38
C3	1/4 to 4	heavy hex	144	144	143	352	B78	C38
D[C]	1/4 to 4	heavy hex	150	150	159	352	B84	C38
DH[D]	1/4 to 4	heavy hex	175	150	248	352	C24	C38
DH3	1/4 to 4	heavy hex	175	150	248	352	C24	C38
A	1/4 to 1 1/2	hex thick	100	75	116	302	B68	C32
B	1/4 to 1	hex thick	133	100	121	302	B69	C32
B	1 1/8 to 1 1/2	hex thick	116	87	121	302	B69	C32
D[C]	1/4 to 1 1/2	hex thick	150	150	159	352	B84	C38
DH[D]	1/4 to 1 1/2	hex thick	175	175	248	352	C24	C38
		Nuts with UNF, 12 UN, and Finer Pitch Threads						
0	1/4 to 1/2	hex	65	49	103	302	B55	C32
A	1/4 to 1 1/2	hex	80	60	116	302	B68	C32
B	1/4 to 1	hex	109	82	121	302	B69	C32
B	1 1/8 to 1 1/2	hex	94	70	121	302	B69	C32
D[C]	1/4 to 1 1/2	hex	135	135	159	352	B84	C38
DH[D]	1/4 to 1 1/2	hex	150	150	248	352	C24	C38
A	1/4 to 4	heavy hex	90	68	116	302	B68	C32
B	1/4 to 1	heavy hex	120	90	121	302	B69	C32
B	1 1/8 to 1 1/2	heavy hex	105	79	121	302	B69	C32
D[C]	1/4 to 4	heavy hex	150	150	159	352	B84	C38
DH[D]	1/4 to 4	heavy hex	175	150	248	352	C24	C38
A	1/4 to 1 1/2	hex thick	90	68	116	302	B68	C32
B	1/4 to 1	hex thick	120	90	121	302	B69	C32
B	1 1/8 to 1 1/2	hex thick	105	79	121	302	B69	C32
D[C]	1/4 to 1 1/2	hex thick	150	150	159	352	B84	C38
DH[D]	1/4 to 1 1/2	hex thick	175	175	248	352	C24	C38

[A] To determine nut proof load in pounds, multiply the appropriate nut proof load stress by the tensile stress area of the thread. Stress areas for UNC, UNF, and 8 UN thread series are given in Table 4.

[B] Non-zinc-coated nuts are nuts intended for use with externally threaded fasteners which have a plain (nonplated or noncoated) finish or have a plating or coating of insufficient thickness to necessitate overtapping the nut thread to provide assemblability. Zinc-coated nuts are nuts intended for use with externally threaded fasteners which are hot-dip zinc-coated, mechanically zinc-coated, or have a plating or coating of sufficient thickness to necessitate overtapping the nut thread to provide assemblability.

[C] Nuts made in accordance to the requirements of Specification A 194/A 194M, Grade 2 or Grade 2H, and marked with their grade symbol are acceptable equivalents for Grades C and D nuts. When A 194 zinc-coated inch series nuts are supplied, the zinc coating, overtapping, lubrication and rotational capacity testing shall be in accordance with Specification A 563.

[D] Nuts made in accordance with the requirements of Specification A 194/A 194M, Grade 2H, and marked with its grade symbol are an acceptable equivalent for Grade DH nuts. When A 194 zinc-coated inch series nuts are supplied, the zinc coating, overtapping, lubrication and rotational capacity testing shall be in accordance with Specification A 563.

TABLE 4
TENSILE STRESS AREAS

Nominal Size — Threads per Inch	UNC Tensile Stress Area,[As] in.^{2}	Nominal Size-Threads per Inch	UNF Tensile Stress Area,[As] in.^{2}	Nominal Size-Threads per Inch	8 UN Tensile Stress Area,[As] in.^{2}
1/4–20	0.0318	1/4–28	0.0364	. . .	. . .
5/16–18	0.0524	5/16–24	0.0580	. . .	. . .
3/8–16	0.0775	3/8–24	0.0878	. . .	. . .
7/16–14	0.1063	7/16–20	0.1187	. . .	. . .
1/2–13	0.1419	1/2–20	0.1599	. . .	. . .
9/16–12	0.182	9/16–18	0.203	. . .	. . .
5/8–11	0.226	5/8–18	0.256	. . .	. . .
3/4–10	0.334	3/4–16	0.373	. . .	. . .
7/8–9	0.462	7/8–14	0.509	. . .	. . .
1–8	0.606	1–12	0.663	1–8	0.606
1 1/8–7	0.763	1 1/8–12	0.856	1 1/8–8	0.790
1 1/4–7	0.969	1 1/4–12	1.073	1 1/4–8	1.000
1 3/8–6	1.155	1 3/8–12	1.315	1 3/8–8	1.233
1 1/2–6	1.405	1 1/2–12	1.581	1 1/2–8	1.492
1 3/4–5	1.90	. . .	. . .	1 3/4–8	2.08
2–4 1/2	2.50	. . .	. . .	2–8	2.77
2 1/4–4 1/2	3.25	. . .	. . .	2 1/4–8	3.56
2 1/2–4	4.00	. . .	. . .	2 1/2–8	4.44
2 3/4–4	4.93	. . .	. . .	2 3/4–8	5.43
3–4	5.97	. . .	. . .	3–8	6.51
3 1/4–4	7.10	. . .	. . .	3 1/4–8	7.69
3 1/2–4	8.33	. . .	. . .	3 1/2–8	8.96
3 3/4–4	9.66	. . .	. . .	3 3/4–8	10.34
4–4	11.08	. . .	. . .	4–8	11.81

[As] The stress area is calculated as follows:

$$A_s = 0.7854 \left[D - \frac{0.9743}{n} \right]^2$$

where:
A_s = stress area, in.^{2},
D = nominal size, in., and
n = threads per inch.

TABLE 5
THREAD DIMENSIONS AND OVERTAPPING ALLOWANCES FOR NUTS
Hot Dip Zinc Coated per Specification A 153, C1. C

Nominal Nut Size, in.	Diametral Allowance, in.[A]	Pitch Diameter, in.	
		min	max
0.250-20	0.016	0.2335	0.2384
0.312-18	0.017	0.2934	0.2987
0.375-16	0.017	0.3514	0.3571
0.437-14	0.018	0.4091	0.4152
0.500-13	0.018	0.4680	0.4745
0.562-12	0.020	0.5284	0.5352
0.625-11	0.020	0.5860	0.5932
0.750-10	0.020	0.7050	0.7127
0.875-9	0.022	0.8248	0.8330
1.000-8	0.024	0.9428	0.9516
1.125-8	0.024	1.0678	1.0768
1.125-7	0.024	1.0562	1.0656
1.250-8	0.024	1.1928	1.2020
1.250-7	0.024	1.1812	1.1908
1.375-8	0.027	1.3208	1.3301
1.375-6	0.027	1.2937	1.3041
1.500-8	0.027	1.4458	1.4553
1.500-6	0.027	1.4187	1.4292
1.750-5	0.050	1.6701	1.6817
2.000-4.5	0.050	1.9057	1.9181
2.500-4.5	0.050	2.3876	2.4011
2.750-4	0.050	2.6376	2.6513
3.000-4	0.050	2.8876	2.9015
3.250-4	0.050	3.1376	3.1517
3.500-4	0.050	3.3876	3.4019
3.750-4	0.050	3.6376	3.6521
3.750-4	0.050	3.6376	3.6521
4.000-4	0.050	3.8876	3.9023

[A] These allowances also apply to the minimum and maximum major and minor diameters.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall be applied only when specified by the purchaser on the contract or order. Details of these supplementary requirements shall be agreed upon in writing between the manufacturer and purchaser. This supplementary requirement shall in no way negate any requirement of the specification itself.

S1. Lubricant and Tightening Test for Coated Nuts

S1.1 Nuts shall be provided with an additional lubricant that shall be clean and dry to the touch.

98 **S1.2** Rotational capacity test procedures, nut rotations, and acceptance criteria are a function of the bolt with which the nuts will be used. They are covered by the applicable bolt specification.

S2. Lubricant Dye

S2.1 The lubricant shall have a color that contrasts with the zinc coating so its presence is visually obvious at the job site.

APPENDIX

(Nonmandatory Information)

X1. INTENDED APPLICATION

X1.1 Table X1.1 gives additional information for the intended application of nuts.

TABLE X1.1
NUT AND BOLT SUITABILITY GUIDE

Grade of Bolt[D]	Surface Finish[E]	Nominal Size, in.	A563 Grade and ANSI Nut Style[A]					
			Recommended[B]		Suitable[C]			
			Hex	Heavy Hex	Square	Hex	Heavy Hex	Hex Thick
A 307 Grade A	non-zinc-coated and zinc-coated	1/4 to 1 1/2	A	. . .	A	B,D,DH	A,B,C,D,DH,DH3	A,B,D,DH
		>1 1/2 to 2	. . .	A	. . .	A[F]	C,D,DH,DH3	. . .
		>2 to 4	. . .	A	. . .	. . .	C,D,DH,DH3	. . .
A 307 Grade B	non-zinc-coated and zinc-coated	1/4 to 1 1/2	. . .	A	A	B,D,DH	B,C,D,DH,DH3	A,B,D,DH
		>1 1/2 to 2	. . .	A	. . .	A[F]	C,D,DH,DH3	. . .
		>2 to 4	. . .	A	. . .	. . .	C,D,DH,DH3	. . .
A 325 Type 1	non-zinc-coated	1/2 to 1 1/2	. . .	C	. . .	. . .	C3,D,DH,DH3	. . .
	zinc-coated	1/2 to 1 1/2	. . .	DH	. . .	. . .	. . .	. . .
A 325 Type 3	non-zinc-coated	1/2 to 1 1/2	. . .	C3	. . .	. . .	DH3	. . .
A 354 Grade BC	non-zinc-coated	1/4 to 1 1/2	. . .	C	. . .	D,DH	C3,D,DH,DH3	D,DH
		>1 1/2 to 4	. . .	C	. . .	. . .	C3,D,DH,DH3	. . .
	zinc-coated	1/4 to 1 1/2	. . .	DH	. . .	. . .	. . .	DH
		>1 1/2 to 4	. . .	DH	. . .	. . .	. . .	. . .
A 354 Grade BD	non-zinc-coated	1/4 to 1 1/2	. . .	DH	. . .	DH	D,DH,DH3	D,DH
		>1 1/2 to 4	. . .	DH	. . .	. . .	DH3	. . .
A 394 Type 0	zinc-coated	1/2 to 1	A	. . .	. . .	B,D	. . .	. . .
A 394 Types 1 and 2	zinc-coated	1/2 to 1	DH	. . .	. . .	D	. . .	. . .
A 394 Type 3	non-zinc-coated	1/2 to 1	DH3	. . .	. . .	. . .	C3	. . .
A 449 Types 1 and 2	non-zinc-coated	1/4 to 1 1/2	B	. . .	. . .	D,DH	B,C,C3,D,DH,DH3	B,D,DH
		>1 1/2 to 3	. . .	A	. . .	. . .	C,C3,D,DH,DH3	. . .
	zinc-coated	1/4 to 1 1/2	. . .	DH	. . .	D,DH	D	D,DH
		>1 1/2 to 3	. . .	DH	. . .	. . .	D	. . .
A 490 Types 1 and 2	non-zinc-coated	1/2 to 1 1/2	. . .	DH	. . .	. . .	DH3	. . .
A 490 Type 3	non-zinc-coated	1/2 to 1 1/2	. . .	DH3	. . .	. . .	. . .	. . .
A 687	non-zinc-coated	1 1/4 to 3	. . .	D	. . .	. . .	DH,DH3	. . .
	zinc-coated	1 1/4 to 3	. . .	DH	. . .	. . .	. . .	. . .

[A] The availability of DH nuts in nominal sizes 3/4 in. and larger is very limited and generally available only on special orders for 50 000 pieces or more. For smaller quantities A 194 Gr. 2H nuts should be considered.

[B] "Recommended" denotes a commercially available nut having the most suitable mechanical properties and dimensional configuration (style) that will make it possible to torque the bolt to the required load when used in combination with the nut.

[C] "Suitable" denotes nuts having mechanical properties that will make it possible to torque the bolt to the required load when used in combination with the nut; but, which require consideration of dimensional configuration (style) suitability and availability. Others are not suitable.

[D] The term "bolt" includes all externally threaded types of fasteners.

[E] Non-zinc-coated nuts are nuts intended for use with externally threaded fasteners which have a plain (nonplated or noncoated) finished or have a plating or coating of insufficient thickness to necessitate overtapping the nut thread to provide assemblability. Zinc-coated nuts are nuts intended for use with externally threaded fasteners which are hot-dip zinc-coated, mechanically zinc-coated, or have a plating or coating of sufficient thickness to necessitate overtapping the nut thread to provide assemblability.

[F] Hex nuts in nominal sizes over 1 1/2 to 2 in. inclusive are not covered in the tables of tabulated sizes in ANSI B18.2.2 but are commercially available. Such nuts are suitable. See 7.2 for dimensions.

SPECIFICATION FOR HOT-ROLLED AND COLD-FINISHED AGE-HARDENING STAINLESS AND HEAT-RESISTING STEEL BARS AND SHAPES

SA-564/SA-564M

(Identical with ASTM Specification A 564/A 564M-92a.)

1. Scope

1.1 This specification covers bars, and shapes of age-hardening stainless and heat-resisting steels. Hot-finished or cold-finished rounds, squares, hexagons, bar shapes, angles, tees, and channels are included; these shapes may be produced by hot rolling, extruding, or forging. Billets or bars for reforging may be purchased to this specification.

1.2 These steels are generally used for parts requiring corrosion resistance and high strength at room temperature, or at temperatures up to 600°F [315°C]; 700°F [370°C] for Type 632. They are suitable for machining in the solution-annealed condition after which they may be age-hardened to the mechanical properties specified in Section 7 without danger of cracking or distortion. Type XM-25 is machinable in the as-received fully heat treated condition.

1.3 Types 631 and 632 contain a large amount of ferrite in the microstructure and can have low ductility in forgings and larger diameter bars. Applications should be limited to small diameter bar.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standards; within the text and tables, the SI units are shown in [brackets]. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

1.5 Unless the order specifies an "M " designation, the material shall be furnished to inch-pound units.

NOTE 1 — For forgings, see Specification A 705/A 705M.
NOTE 2 — For billets and bars for forging see Specification A 314.

2. Referenced Documents

2.1 *ASTM Standards:*

A 314 Specification for Stainless and Heat-Resisting Steel Billets and Bars for Forging

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 484/A 484M Specification for General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings

A 705/A 705M Specification for Age-Hardening, Stainless and Heat-Resisting Steel Forgings

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *Other Documents:*

SAEJ1086 Recommended Practice for Numbering Metals and Alloys (UNS)

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Quantity (weight or number of pieces),

3.1.2 Type or UNS designation (Table 1),

3.1.3 Heat treated condition (5.1),

3.1.4 Transverse properties when required (7.6),

3.1.5 Finish (Specification A 484/A 484M),

3.1.6 Surface preparation of shapes (5.2),

3.1.7 Size, or applicable dimension including diameter, thickness, width, length, etc.,

3.1.8 Preparation for delivery (Specification A 484/A 484M),

3.1.9 Special requirements (refer to 7.4 and 8.3),

3.1.10 Marking requirements (Specification A 484/A 484M), and

3.1.11 ASTM designation and date of issue if other than that currently published.

3.2 If possible, the intended use of the item should be given on the purchase order especially when the item is ordered for a specific end use or uses.

NOTE 3 — A typical ordering description is as follows: 5000 lb [2270 kg] Type 630, Solution-Annealed Cold Finished Centerless Ground, $1\frac{1}{2}$ in. [38.0 mm] round bar, 10 to 12 ft [3.0 to 3.6 m] in length. ASTM A 564 dated —. End use: valve shafts.

4. General Requirements

4.1 In addition to the requirements of this specification, all requirements of the current edition of Specifications A 484/A 484M shall apply. Failure to comply with the general requirements of Specification A 564/A 564M constitutes nonconformance with this specification.

5. Manufacture

5.1 *Heat Treatment:*

5.1.1 Material of types other than XM-16, XM-25, and Type 630 shall be furnished in the solution-annealed condition, or in the equalized and oven-tempered condition, as noted in Table 2, unless otherwise specified by the purchaser.

5.1.1.1 Types 630, XM-16, and XM-25 may be furnished in the solution-annealed or age-hardened condition.

5.1.2 Reforging stock shall be supplied in a condition of heat treatment to be selected by the forging manufacturer.

5.2 Shapes may be subjected to either Class A or Class C preparation as specified on the purchase order.

5.2.1 Class A consists of preparation by grinding for the removal of imperfections of a hazardous nature such as fins, tears, and jagged edges provided the underweight tolerance is not exceeded and the maximum depth of grinding at any one point does not exceed 10% of the thickness of the section.

5.2.2 Class C consists of preparation by grinding for the removal of all visible surface imperfections provided the underweight tolerance is not exceeded and the maximum depth of grinding at any one point does not exceed 10% of the thickness of the section.

6. Chemical Composition

6.1 Each alloy covered by this specification shall conform to the chemical requirements specified in Table 1.

6.2 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

7. Mechanical Properties Requirements

7.1 The material, as represented by mechanical test specimens, shall conform to the mechanical property requirements specified in Table 2 and shall be capable of developing the properties in Table 3 when heat treated as specified in Section 5.1.

7.2 Samples cut from bars for forging stock shall conform to the mechanical properties of Tables 2 and 3 when heat treated as specified in Tables 2 and 3.

7.3 The yield strength shall be determined by the offset method as described in the current edition of Test Methods and Definitions A 370. The limiting permanent offset shall be 0.2% of the gage length of the specimen.

7.4 The impact requirement shall apply only when specified in the purchase order. When specified, the material, as represented by impact test specimens, shall be capable of developing the impact property requirements specified in Table 3 when heat treated in accordance with Section 5.1.

7.5 Longitudinal impact requirements are not applicable to bars less than $\frac{5}{8}$ in. (16.9 mm) diameter in size or flats less than $\frac{5}{8}$ in. (16.9 mm) thick.

7.6 Tensile and impact requirements in the transverse (through thickness) direction are not applicable to bars less than 3 in. [75 mm] diameter in size or flats less than 3 in. [75 mm] thick.

7.7 Material tensile tested and, when specified, impact tested in the transverse (through thickness) direction and meeting the requirements shown in Table 3 need not be tested in the longitudinal direction.

8. Number of Tests

8.1 At least one room temperature tension test and one or more hardness tests shall be made on each lot.

8.2 One or more hardness tests and at least one tension test shall be made from each lot on test samples heat treated as required in Section 5.1. Unless otherwise specified in the purchase order, the condition of hardening heat treatment shall be at the option of the producer. The tests shall meet the requirements of Table 3.

8.3 When specified in the purchase order, the impact test shall consist of testing three Charpy V-notch Type A specimens in accordance with Methods and Definitions A 370. The specimens shall be heat treated in accordance with Section 5.1. Unless otherwise specified in the purchase order, the condition of hardening heat treatment shall be at the option of the producer and testing shall be done at 70 to 80°F [20 to 25°C]. The tests shall meet the requirements of Table 3. When tested at temperatures other than 70 to 80°F [20 to 25°C], the impact test requirements will be as agreed upon by purchaser and producer.

TABLE 1
CHEMICAL REQUIREMENTS[A]

Composition, %													
UNS Designation[G]	Type	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Aluminum	Molybdenum	Titanium	Copper	Other Elements
S17400	630	0.07	1.00	0.040	0.030	1.00	15.00–17.50	3.00–5.00	. . .	. . .	. . .	3.00–5.00	[B]
S17700	631	0.09	1.00	0.040	0.030	1.00	16.00–18.00	6.50–7.75	0.75–1.50	. . .	. . .	. . .	. . .
S15700	632	0.09	1.00	0.040	0.030	1.00	14.00–16.00	6.50–7.75	0.75–1.50	2.00–3.00	. . .	. . .	. . .
S35500	634	0.10–0.15	0.50–1.25	0.040	0.030	0.50	15.00–16.00	4.00–5.00	. . .	2.50–3.25	. . .	. . .	[C]
S17600	635	0.08	1.00	0.040	0.030	1.00	16.00–17.50	6.00–7.50	0.40	. . .	0.40–1.20	. . .	. . .
S15500	XM-12	0.07	1.00	0.040	0.030	1.00	14.00–15.50	3.50–5.50	. . .	. . .	. . .	2.50–4.50	[B]
S13800	XM-13	0.050	0.20	0.010	0.008	0.10	12.25–13.25	7.50–8.50	0.90–1.35	2.00–2.50	. . .	. . .	[D]
S45500	XM-16	0.03	0.50	0.015	0.015	0.50	11.00–12.50	7.50–9.50	. . .	0.50	0.90–1.40	1.50–2.50	[E]
S45503	. . .	0.010	0.50	0.010	0.010	0.20	11.00–12.50	7.50–9.50	. . .	0.50	1.00–1.35	1.50–2.50	[E]
S45000	XM-25	0.05	1.00	0.030	0.030	1.00	14.00–16.00	5.00–7.00	. . .	0.50–1.00	. . .	1.25–1.75	[F]

[A] Limits are in percent maximum unless shown as a range or stated otherwise.
[B] Columbium plus tantalum 0.15–0.45.
[C] Nitrogen 0.07–0.13.
[D] Nitrogen 0.01.
[E] Columbium plus tantalum 0.10–0.50.
[F] Columbium 8 times carbon minimum.
[G] New designation established in accordance with Practice E 527 and SAEJ1086.

TABLE 2
SOLUTION TREATMENT

UNS Designation	Type	Condition	Solution Treatment	Mechanical Test Requirements in Solution Treated Condition[A]							
				Tensile Strength, min		Yield Strength, min[B]		Elongation in 2 in. [50 mm] or 4D, min. %	Reduction of Area, min %	Hardness[C]	
				ksi	[MPa]	ksi	[MPa]			Rockwell C, max	Brinell, max
S17400	630	A	1900 ± 25°F [1040 ± 15°C] (cool as required to below 90°F (32°C))	...	...	...	...	...	...	38	363
S17700	631	A	1900 ± 25°F [1040 ± 15°C] (water quench)	...	...	...	...	...	...	Rb98	229
S15700	632	A	1900 ± 25°F [1040 ± 15°C] (water quench)	...	...	...	...	...	...	Rb100	269[D]
S35500	634[E]	A	1900 ± 25°F [1040 ± 15°C] quench, hold not less than 3 h at minus 100°F or lower	...	...	...	...	...	...	...	363[E]
S17600	635	A	1900 ± 25°F [1040 ± 15°C] (air cool)	120	[825]	75	[515]	10	45	32	302
S15500	XM-12	A	1900 ± 25°F [1040 ± 15°C] (cool as required to below 90°F (32°C))	...	...	...	...	...	...	38	363
S13800	XM-13	A	1700 ± 25°F [925 ± 15°C] Cool as required to below 60°F [16°C]	...	...	...	...	...	...	38	363
S45500	XM-16	A	1525 ± 25°F [830 ± 15°C] (cool rapidly)	...	...	...	...	...	...	36	331
S45000	XM-25	A	1900 ± 25°F [1040 ± 15°C] (cool rapidly)	130[F]	[895]	95	[655]	10	40	32	321
S45503	...	A	1525 ± 25°F [830 ± 15°C] (cool rapidly)	...	...	...	...	...	...	36	331

[A] See 7.1.
[B] See 7.2.
[C] Either Rockwell C hardness or Brinell is permissible. On sizes ½ in. (12.70 mm) and smaller, Rockwell C is preferred.
[D] 321 BH for rounds cold drawn after solution treating.
[E] Equalization and over-tempering treatment 1425 ± 50°F (775 ± 30°C] for not less than 3 h, cool to room temperature, heat to 1075 ± 25°F [580 ± 15°C] for not less than 3 h.
[F] 130–165 ksi [895–1140 MPa] for sizes up to ½ in. (13 mm).

TABLE 3
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A]

Type	Condition	Suggesting Hardening or Aging Treatment, or both[M,N,P]			Applicable Thickness, in. and Test Direction[F]	Tensile Strength, min		Yield Strength, min[B]		Elongation in 2 in. [50 mm] or 4D, min. %	Reduction of area, min, %	Hardness[G]		Impact Charpy-V, min	
		Temperature, °F [°C]	Time, h	Quench		ksi	[MPa]	ksi	[MPa]			Rockwell C, min	Brinell, min	ft · lbf	J
630	H900	900 [480]	1.0	air cool	Up to 3 in. incl [75 mm] (L)	190	[1310]	170	[1170]	10	40	40	388	...	...
					Over 3 in. [75 mm] to 8 in. incl [200 mm] (L)						35				
	H925	925 [495]	4.0	air cool	Up to 3 min. incl [75 mm] (L)	170	[1170]	155	[1070]	10	44	38	375	5	6.8
					Over 3 in. [75 mm] to 8 in. incl [200 mm] (L)						38				
	H1025	1025 [550]	4.0	air cool		155	[1070]	145	[1000]	12	45	35	331	15	20
	H1075	1075 [580]	4.0	air cool		145	[100]	125	[860]	13	45	32	311	20	27
	H1100	1100 [595]	4.0	air cool	Up to 8 in. incl [200 mm] (L)	140	[965]	115	[795]	14	45	31	302	25	34
	H1150	1150 [620]	4.0	air cool		135	[930]	105	[725]	16	50	28	277	30	41
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool				115	[795]	75	[515]	18	55	24	255	55	75
631	RH950	1750°F [955°C] for not less than 10 min, but not more than 1 h, cool rapidly to room temperature. Cool within 24 h to minus 100 ± 10°F [75°C], hold not less than 8 h. Warm in air to room temperature. Heat to 950°F [510°C], hold 1 h, air cool.			Up to 4 in. incl. [100 mm] (L)	185	[1275]	150	[1035]	6	10	41	388	...	...
	TH1050	Alternative treatment: 1400°F [760°C] hold 90 min, cool to 55 ± 5°F [15 ± 3°C] within 1 h. Hold not less than 30 min, heat to 1050°F [565°C] hold for 90 min, air cool.			Up to 6 in. incl [150 mm] (L)	170	[1170]	140	[965]	6	25	38	352	...	...
632	RH950				Up to 4 in. incl [100 mm] (L)	200	[1380]	175	[1210]	7	25	...	415	...	...
	TH1050	Same as Type 631			Up to 6 in. incl [150 mm] (L)	180	[1240]	160	[1100]	8	25	...	375	...	...
634[C]	H1000	1750 [955] for not less than 10 min, but not more than 1 h. Water quench. Cool to not higher than minus 100°F [75°C]. Hold for not less than 3 h. Temper at 1000°F [540°C], holding for not less than 3 h.				170	[1170]	155	[1070]	12	25	37	341	...	...
635	H950	950 [510]	0.5	air cool		190	[1310]	170	[1170]	8	25	39	363	...	...
	H1000	1000 [540]	0.5	air cool		180	[1240]	160	[1100]	8	30	37	352	...	...
	H1050	1050 [565]	0.5	air cool		170	[1170]	150	[1030]	10	40	35	331	...	...
XM-12	H900	900 [480]	1.0	air cool	Up to 12 in. incl [300 mm][D] (L)	190	[1310]	170	[1170]	10	35	40	388	...	...
					Up to 12 in. incl [300 mm][D] (T)					6	15				
	H925	925 [495]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	170	[1170]	155	[1070]	10	38	38	375	5	6.8
					Up to 12 in. incl [300 mm][D] (T)					7	20			...	...

TABLE 3 (CONT'D)
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A]

Type	Condition	Suggesting Hardening or Aging Treatment, or both[M,N,P]			Applicable Thickness, in. and Test Direction[F]	Tensile Strength, min		Yield Strength, min[B]		Elongation in 2 in. [50 mm] or 4D, min. %	Reduction of area, min, %	Hardness[G]		Impact Charpy-V, min	
		Temperature, °F [°C]	Time, h	Quench		ksi	[MPa]	ksi	[MPa]			Rockwell C, min	Brinell, min	ft · lbf	J
XM12	H1025	1025 [550]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	155	[1070]	145	[1000]	12	45	35	331	15	20
					Up to 12 in. incl [300 mm][D] (T)					8	27			10	14
	H1075	1075 [580]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	145	[1000]	125	[860]	13	45	32	311	20	27
					Up to 12 in. incl [300 mm][D] (T)					9	28			15	20
	H1100	1100 [595]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	140	[965]	115	[795]	14	45	31	302	25	34
					Up to 12 in. incl [300 mm][D] (T)					10	29			15	20
	H1150	1150 [620]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	135	[930]	105	[725]	16	50	28	277	30	41
					Up to 12 in. incl [300 mm][D] (T)					11	30			20	27
	H1150M	1400 [760] for 2 h, air cool plus 1150 [620] for 4 h, air cool			Up to 12 in. incl [300 mm][D] (L)	115	[795]	75	[515]	18	55	24	255	55	75
					Up to 12 in. incl [300 mm][D] (T)					14	35			35	47
XM-13	H950	950 [510]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	220	[1520]	205	[1410]	10	45	45	430	...	...
					Up to 12 in. incl [300 mm][D] (T)						35				
	H1000	1000 [540]	4.0	air cool	Up to 12 in. incl [300 mm][D] (L)	205	[1410]	190	[1310]	10	50	43	400	...	...
					Up to 12 in. incl [300 mm][D] (T)					10	40				
	H1025	1025 [550]	4.0	air cool	Up to 12 in. inc [300 mm] (L)	185	[1275]	175	[1210]	11	50	41	380	...	...
					Up to 12 in. incl [300 mm] (T)						45				
	H1050	1050 [565]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	175	[1210]	165	[1140]	12	50	40	372	...	...
					Up to 12 in. incl [300 mm] (T)						45				
	H1100	1100 [540]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	150	[1030]	135	[930]	14	50	34	313	...	...
					Up to 12 in. incl [300 mm] (T)						50				
	H1150	1150 [620]	4.0	air cool	Up to 12 in. incl [300 mm] (L)	135	[930]	90	[620]	14	50	30	283	...	...
					Up to 12 in. incl [300 mm] (T)						50				
	H1150M	1400 (760) for 2 h, air cool plus 1150 [620] for 4 h, air cool			Up to 12 in. incl [300 mm] (L)	125	[860]	85	[585]	16	55	26	259	...	...
					Up to 12 in. incl [300 mm] (T)						55				

TABLE 3 (CONT'D)
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A]

Type	Condition	Suggesting Hardening or Aging Treatment, or both[M,N,P]			Applicable Thickness, in. and Test Direction[F]	Tensile Strength, min		Yield Strength, min[B]		Elongation in 2 in. [50 mm] or 4D, min. %	Reduction of area, min, %	Hardness[G]		Impact Charpy-V, min	
		Temperature, °F [°C]	Time, h	Quench		ksi	[MPa]	ksi	[MPa]			Rockwell C, min	Brinell, min	ft · lbf	J
XM-16[H]	H900	900 [480]	4.0	air cool	Up to 6 in. incl [150 mm] (L)	235	[1620]	220	[1520]	8	30	47	444	...	...
	H950	950 [510]	4.0	air cool		220	[1520]	205	[1410]	10	40	44	415	...	...
	H1000	1000 [540]	4.0	air cool		205	[1410]	185	[1280]	10	40	40	363	...	...
S45503[H]	H900	900 [480]	4.0	air cool	Up to 6 in. incl [150 mm] (L) Up to 6 in. incl [150 mm][K] (T)	235	[1620]	220	[1515]	8 4	30 15	47	444	...	...
	H950	950 [510]	4.0	air cool	Up to 6 in. incl [150 mm] (L) Up to 6 in. incl [150 mm][K] (T)	220	[1520]	205	[1415]	10 5	40 20	44	415	...	...
	H1000	1000 [540]	4.0	air cool	Up to 6 in. incl [150 mm] (L) Up to 6 in. incl [150 mm][K] (T)	205	[1410]	185	[1280]	10 6	40 25	40	363	...	...
XM-25[H]	H900	900 [480]	4.0	air cool	Up to 8 in. incl [200 mm] (L) Up to 12 in. incl [300 mm][K] (L) Up to 12 in. incl. [300 mm][K] (T)	180	[1240]	170	[1170]	10 10 6	40 40 20	39	363	...	...
	H950	950 [510]	4.0	air cool	Up to 8 in. incl [200 mm][Q] (L) Up to 12 in. incl [300 mm][K] (L) Up to 12 in. incl [300 mm][K] (T)	170	[1170]	160	[1100]	10 10 7	40 40 22	37	341	...	...
	H1000	1000 [540]	4.0	air cool	Up to 8 in. incl [200 mm][Q] (L) Up to 12 in. incl [300 mm][K] (L) Up to 12 in. incl [300 mm][K] (T)	160	[1100]	150	[1030]	12 12 8	45 45 27	36	331	...	...
	H1025	1025 [550]	4.0	air cool	Up to 8 in. incl [200 mm][Q] (L)	150	[1030]	140	[965]	12	45	34	321	...	...
	H1050	1050 [565]	4.0	air cool	Up to 8 in. incl [200 mm][Q] (L) Up to 12 in. incl [300 mm][K] (L) Up to 12 in. incl [300 mm][K] (T)	145	[1000]	135	[930]	12 12 9	45 45 30	34	321	...	...
	H1100	1100 [595]	4.0	air cool	Up to 8 in. incl [200 mm][Q] (L) Up to 12 in. incl [300 mm][K] (L) Up to 12 in. incl [300 mm][K] (T)	130	[895]	105	[725]	16 16 11	50 50 30	30	285	...	...

TABLE 3 (CONT'D)
MECHANICAL TEST REQUIREMENTS AFTER AGE HARDENING HEAT TREATMENT[A]

Type	Condition	Suggesting Hardening or Aging Treatment, or both[M,N,P]			Applicable Thickness, in. and Test Direction[F]	Tensile Strength, min		Yield Strength, min[B]		Elongation in 2 in. [50 mm] or 4D, min. %	Reduction of area, min, %	Hardness[G]		Impact Charpy-V, min	
		Temperature, °F [°C]	Time, h	Quench		ksi	[MPa]	ksi	[MPa]			Rockwell C, min	Brinell, min	ft · lbf	J
	H1150	1150 [610]	4.0	air cool	Up to 8 in. incl [200 mm][Q] (L)	125	[860]	75	[520]	15	50	26	262	...	...
					Up to 12 in. incl [300 mm][K] (L)					18	55				
					Up to 12 in. incl [300 mm][K] (T)					12	35				

[A] See 7.1
[B] See 7.2
[C] Refer to Table 2 for details on equalize and over temper heat treatment.
[D] Applies to consumable electrode vacuum remelted.
[F] (L) — Longitudinal axis of specimen parallel to direction of grain flow during rolling or forging. (T) — Transverse axis of specimen perpendicular to direction of grain flow during rolling or forging.
[G] Either Rockwell C or Brinell is permissible. On sizes ½ in. (12.70 mm) and smaller, Rockwell C is preferred.
[H] Only tensile strength applicable to sizes up to ½ in. (13 mm).
[K] Consumable electrode remelted only.
[M] Time refers to minimum time material is at temperature and may be extended to obtain required ductility properties.
[N] Unless otherwise noted, temperatures shown are suggested temperatures and may be varied to obtain required tensile properties.
[P] Intermediate temperatures must meet the ductility requirements of the next highest suggested hardening or aging temperature, or both. Example: Type 630 at 1050°F [565°C] must have 13% elongation and 45% reduction, same as for age hardening at 1075°F [580°C].
[Q] Air melt.

SPECIFICATION FOR ALLOY STEEL SOCKET-HEAD SCREWS

SA-574

(Based on ASTM Specifications A 325-80a and A 574-82. Material conforming to A 574-82 can usually be requalified to conform to this specification.)

1. Scope

1.1 This specification covers the requirements for quenched and tempered alloy steel hexagon socket-head cap screws, 0.060 through 4 in. in diameter where high strength is required.

2. Applicable Documents

2.1 *ASTM Standards:*

A 370 Methods and Definitions for Mechanical Testing of Steel Products

A 751 Methods, Practices, and Definitions for Chemical Analysis of Steel Products

E 3 Preparation of Metallographic Specimens

F 606 Conducting Tests to Determine the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

2.2 *ANSI Standards:*

ANSI B1.1 Unified Screw Threads

ANSI B18.3 Socket Cap, Shoulder, and Set Screws

2.3 *Federal Standard:*

Fed. Std. H28

3. Definitions

3.1 Definitions of discontinuities covered by 9.2 follow:

3.1.1 *crack* — a clean crystalline break passing through the grain or grain boundary without inclusion of foreign elements.

3.1.2 *seam or lap* — a noncrystalline break through the metal which is inherently in the raw material.

3.1.3 *inclusions* — particles of nonmetallic impurities, usually oxides, sulfides, silicates, and such, which are mechanically held in the steel during solidification.

3.1.4 *nicks or pits* — depressions or indentations in the surface of the metal.

4. Ordering Information

4.1 Orders for socket head cap screws under this specification shall include the following:

4.1.1 Specification designation and date of issue,

4.1.2 Quantities (number of pieces by size),

4.1.3 Size and length,

4.1.4 Specify if inspection at point of manufacture is required,

5. Material and Manufacture

5.1 The screws shall be fabricated from a steel which has been made by the open-hearth, basic-oxygen, or electric-furnace process.

5.2 Unless otherwise specified, the heads of screws through 1.500 in. diameter shall be fabricated by hot or cold forging. Over 1.500 in. diameter, the heads may be fabricated by hot or cold forging or by machining. Sockets may be forged or machined.

5.3 Unless otherwise specified, threads of screws shall be rolled for diameters through 0.625 in. and for screw lengths through 4 in. For diameters and lengths other than this, threads may be rolled, cut, or ground.

5.4 The screws shall be heat treated by oil quenching from above the transformation temperature and then tempering at a temperature not lower than 650°F.

6. Chemical Requirements

6.1 The heat analysis of the screw material shall conform to the chemical composition, specified in Table 1.

6.2 Product analyses may be made by the purchaser from finished material representing each lot. The chemical composition, thus determined, shall conform to the requirements prescribed for product analysis in Table 1.

6.3 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

6.4 Chemical analyses shall be performed in accordance with Methods A 751.

7. Mechanical Requirements

7.1 The hardness of finished screws shall be 39 to 45 HRC for 0.500 in. and smaller and 37 to 45 HRC for 0.625 in. and larger. This shall be only the mechanical requirement for screws that are shorter than three times the diameter or that have insufficient threads for tension testing.

7.2 Screws, other than those exempted in 7.1 and 7.3, shall meet the proof load and tensile requirements in Tables 2 and 3. The screws shall be tension tested with a wedge of the angle specified in Table 5 under the head. To meet the requirements of the wedge test, there must be a tensile failure in the body or thread section. For the purpose of this test, failure means separation into two pieces. Screws threaded to the head shall pass the requirements for this test if the fracture that caused failure originated in the thread area, even though it may have propagated into the fillet area or the head before separation.

7.3 Screws having a diameter larger than 1.250 in. shall be preferably tested in full size and shall meet the requirements of Tables 2 and 3. When equipment of sufficient capacity is not readily available, screws shall meet 170 ksi, min, tensile strength, 135 ksi, min, yield strength at 0.2% offset, and 8% elongation on specimens machined in accordance with Methods and Definitions A 370.

8. Dimensions

8.1 Unless otherwise specified, the product shall conform to the requirements of ANSI B18.3.

8.2 Unless otherwise specified, threads shall be Unified standard: Class 3A, UNC and UNF series for screw sizes 060 through 1 in. incl; Class 2A, UNC and UNF series for sizes over 1 in. to 1.500 in. incl; and Class 2A UNC series for sizes larger than 1.500 in. in accordance with ANSI B1.1.

9. Workmanship and Finish

9.1 *Carburization or Decarburization:*

9.1.1 There shall be no evidence of carburization or total decarburization on the surfaces of the heat-treated screws when measured in accordance with 10.3.

9.1.2 The depth of partial decarburization shall be limited to the values in Table 4 when measured as shown in Fig. 1 and in accordance with 10.3.

9.2 *Discontinuities:*

9.2.1 *Socket Discontinuities:*

9.2.1.1 Depth of discontinuities in the socket area will be permissible within the limits of Condition 1 provided they do not affect the usability and performance of the screw. Discontinuities exceeding these limits are not acceptable.

9.2.1.2 Longitudinal discontinuities must not exceed 0.25T in length. Permissible and nonpermissible discontinuities are shown in Fig. 2.

NOTE 2 — T = actual key engagement.

9.2.2 *Permissible Head and Body Discontinuities* — Discontinuities as defined above are permitted in the locations illustrated in Fig. 3 to the depths shown below. These discontinuities are permitted, provided they do not affect the usability and performance of the screw. All discontinuities are to be measured perpendicular to indicated surfaces.

9.2.3 Conditions for permissible discontinuity depths:

9.2.3.1 *Condition 1* — For bearing area, fillet, and other surfaces, max depth = 0.03*D* or 0.005 in. (whichever is greater).

NOTE 3 — *D* = nominal diameter of screw.

9.2.3.2 *Condition 2* — For peripheral discontinuities, max depth = 0.06*D*, but not to exceed 0.064.

9.2.4 *Thread Discontinuities* — Threads shall have no laps at the root or on the flanks located below the pitch line. Laps are permissible at the thread crest to a depth of 25% of the basic thread height and on the thread flanks beyond the pitch diameter. Longitudinal seams in the threads are acceptable within the limits of Condition 1 (9.2.3.1).

10. Test Methods

10.1 Test the finished screws and specimens, as applicable, for mechanical properties and hardness requirements of Section 6. Testing shall be in accordance with Methods A 370 at room temperature. The minimum required length for tension testing shall be 3*D*. The angle used in wedge tests shall be as specified in Table 5.

10.2 The speed of testing, as determined with a free running crosshead, shall be a maximum of 1 in./min. for the tension tests of screws.

10.3 To test for decarburization and carburization, section the thread area of the bolt longitudinally through the axis, mount, and polish it in accordance with Methods E 3. Measure (*1*) at the root and (*2*) from a point in the center of the root along the same plane as the root, perpendicularly to the crest. Use one of two methods for the root to crest measurement, either optical or microhardness measurement. The microhardness measurement shall constitute the referee method in cases of dispute.

10.3.1 For optical measurement, etch the section in 4% nital. Examine the surface of the etched samples under a microscope at 100× using a measuring eyepiece graduated in 0.001 in. increments. The width of any light etching band normally defines the decarburization depth. A dark etching band indicates the possibility of carburization.

10.3.2 Measure microhardness on unetched specimens using a DPH 136° indentor or a Knoop indenter with a 200 gf load. Measure at the root diameter (Reading Number 1) on the thread crest bisector to determine base material hardness. Measure (Reading Number 2) on the bisector 0.75 h_S from the root measurement toward the thread crest. Measure (Reading Number 3) also within 0.003 of the thread flank at the pitch line on this or adjacent thread. The hardness reading (No. 2) at 0.75 h_S shall be equal to or greater than the base material (No. 1) hardness minus 30 DPH, and shall be the decarburization limit determinant. Determine the depth of decarburization in the root of the thread by making hardness measurement at 0.1 *h*, below the root surface (Reading Number 4). The hardness reading (No. 4) in the root shall be equal to or greater than the base material (No. 1) hardness minus 30 DPH. None of the hardness readings (No. 2, 3, or 4) shall be greater than the base material (No. 1) hardness plus 10 DPH.

11. Quality Assurance of Mechanical Requirements

11.1 The manufacturer shall make sample inspections of every lot of bolts to ensure that properties of bolts are in conformance with the requirements of this specification. All bolts shall be inspection tested prior to shipment in accordance with one of the two quality assurance procedures described in 11.2 and 11.3, respectively. The manufacturer shall have the option of which procedure will be followed when furnishing bolts to any single purchase order.

11.1.1 The purpose of a lot inspection testing program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective it is essential that following delivery the purchaser continue to maintain the identification and integrity of each lot until the product is installed in its service application.

11.2 *Production Lot Method:*

11.2.1 All bolts shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer shall identify and maintain the integrity of each production lot of bolts from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

11.2.2 A production lot, for purposes of assigning an identification number and from which test samples shall be selected, shall consist of all bolts processed essentially together through all operations to the shipping container that are of the same nominal size, the

same nominal length, and produced from the same mill heat of steel.

11.2.3 The manufacturer shall make tests for tensile strength (wedge test), when applicable, and hardness of each lot of bolts.

11.2.4 From each production lot, the minimum number of tests of each required property shall be as follows:

Number of Pieces in Production Lot	Number of Specimens
800 and less	1
801 to 8,000	2
8,001 to 35,000	3
35,001 to 150,000	8
150,001 and over	13

11.2.5 If any test specimen shows defective machining it may be discarded and another specimen substituted.

11.2.6 Bolts shall be packed in shipping containers as soon as practicable following final processing. Shipping containers shall be marked with the lot identification number.

11.2.7 A copy of the inspection report for each production lot from which bolts are supplied to fill the requirements of a shipment shall be furnished to the purchaser. Individual heats of steel need not be identified on the test report.

11.3 *Shipping Lot Method:*

11.3.1 In-process inspection during all manufacturing operations and treatments and storage of manufactured bolts shall be in accordance with the practices of the individual manufacturer.

11.3.2 Before packing bolts for shipment, the manufacturer shall make tests of sample bolts taken at random from each shipping lot. A shipping lot, for purposes of selecting test samples, is defined as that quantity of bolts of the same nominal size and same nominal length necessary to fill the requirements of a single purchase order.

11.3.3 The manufacturer shall make tests for tensile strength (wedge test), when applicable, and hardness of each lot of bolts, including proof load tests.

11.3.4 From each shipping lot, the minimum number of tests of each required property shall be as follows:

Number of Pieces in Shipping Lot	Number of Specimens
150 and less	1
151 to 280	2
281 to 500	3
501 to 1,200	5
1,201 to 3,200	8
3,201 to 10,000	13
10,001 and over	20

11.3.5 If any test specimen shows defective machining it may be discarded and another specimen substituted.

11.3.6 A copy of the inspection test report for each shipping lot shall be furnished to the purchaser. Individual heats of steel are not identified in the finished product.

11.4 When tested in accordance with the required sampling plan, a lot shall be rejected if any of the test specimens fail to meet the applicable test requirements.

12. Inspection

12.1 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

13. Rejection

13.1 Rejections based on requirements herein shall be reported to the manufacturer within 30 days after receipt of material by the purchaser.

14. Packaging and Shipping

14.1 The manufacturer shall employ such methods of packaging the screws as may be reasonably required to ensure their receipt by the purchaser in a satisfactory condition.

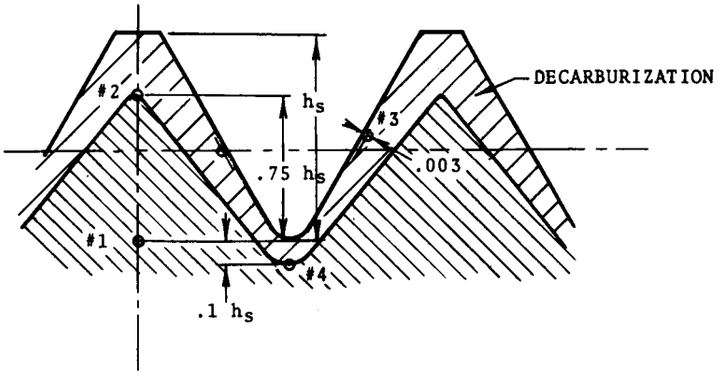


FIG. 1 DEFINITION OF PARTIAL DECARBURIZATION LIMITS

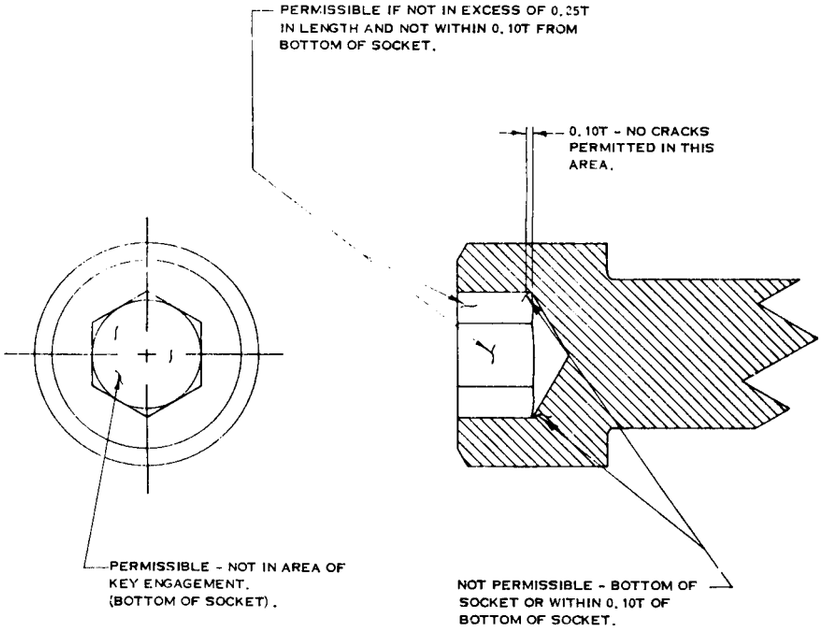


FIG. 2 SOCKET DISCONTINUITY LOCATION AND LIMITS

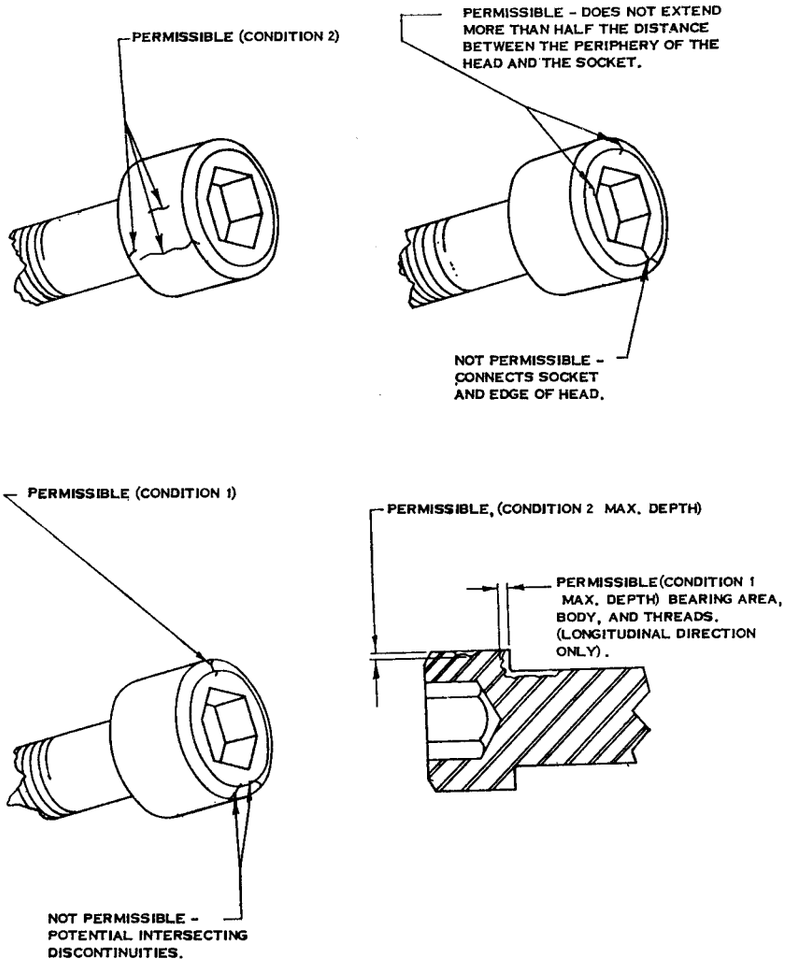


FIG. 3 HEAD AND BODY DISCONTINUITY LOCATION AND LIMITS

TABLE 1
CHEMICAL COMPOSITION

Grade Designation	4037	4042	4137	4140	4142	4145	4340	8740	5137M	51B37M
UNS Number	G40370	G40420	G41370	G41400	G41420	G41450	G43400	—		
Carbon										
Heat Analysis	0.35–0.40	0.40–0.45	0.35–0.40	0.38–0.43	0.40–0.45	0.43–0.48	0.38–0.43	0.38–0.43	0.35–0.40	0.33–0.40
Product Analysis	0.33–0.42	0.38–0.47	0.33–0.42	0.36–0.45	0.38–0.47	0.41–0.50	0.36–0.45	0.36–0.45	0.33–0.42	0.31–0.42
Manganese										
Heat Analysis	0.70–0.90	0.70–0.90	0.70–0.90	0.75–1.00	0.75–1.00	0.75–1.00	0.60–0.80	0.75–1.00	0.30–0.50	0.30–0.50
Product Analysis	0.67–0.93	0.67–0.93	0.67–0.93	0.71–1.04	0.71–1.04	0.71–1.04	0.57–0.83	0.71–1.04	0.27–0.53	0.27–0.53
Phosphorus, max.										
Heat Analysis	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Product Analysis	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Sulfur, max.										
Heat Analysis	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Product Analysis	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Silicon										
Heat Analysis	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35	0.15–0.35
Product Analysis	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37	0.13–0.37
Nickel										
Heat Analysis	—	—	—	—	—	—	1.65–2.00	0.40–0.70	—	—
Product Analysis	—	—	—	—	—	—	1.60–2.05	0.37–0.73	—	—
Chromium										
Heat Analysis	—	—	0.80–1.10	0.80–1.10	0.80–1.10	0.80–1.10	0.70–0.90	0.40–0.60	0.90–1.20	0.95–1.25
Product Analysis	—	—	0.75–1.15	0.75–1.15	0.75–1.15	0.75–1.15	0.67–0.93	0.37–0.63	0.85–1.25	0.90–1.30
Molybdenum										
Heat Analysis	0.20–0.30	0.20–0.30	0.15–0.25	0.15–0.25	0.15–0.25	0.15–0.25	0.20–0.30	0.20–0.30	—	—
Product Analysis	0.18–0.32	0.18–0.32	0.13–0.27	0.13–0.27	0.13–0.27	0.13–0.27	0.18–0.32	0.18–0.32	—	—
Boron										0.0005–
Heat Analysis	—	—	—	—	—	—	—	—	—	0.003
Product Analysis	—	—	—	—	—	—	—	—	—	*

* Boron is not subject to product analysis.

TABLE 2
TENSILE REQUIREMENTS FOR COARSE THREAD SCREWS

Screw Dia (*D*), in.	Threads/ in.	Tensile Load, min, lbf[a]	Stress Area, in.^{2}[b]	Proof Load (Length Measurement Method), min, lbf[c]
0.073	64	473	0.00263	368
0.086	56	666	0.00370	518
0.099	48	877	0.00487	682
0.112	40	1 090	0.00604	846
0.125	40	1 430	0.00796	1 110
0.138	32	1 640	0.00909	1 270
0.164	32	2 520	0.0140	1 960
0.190	24	3 150	0.0175	2 450
0.250	20	5 730	0.0318	4 450
0.3125	18	9 440	0.0524	7 340
0.375	16	13 900	0.0775	10 800
0.4375	14	19 100	0.1063	14 900
0.500	13	25 500	0.1419	19 900
0.625	11	38 400	0.226	30 500
0.750	10	56 800	0.334	45 100
0.875	9	78 500	0.462	62 400
1.000	8	103 000	0.606	81 800
1.125	7	129 000	0.763	103 000
1.250	7	165 000	0.969	131 000
1.375	6	196 000	1.155	156 000
1.500	6	239 000	1.405	190 000
1.750	5	323 000	1.90	256 000
2.000	4½	425 000	2.50	338 000
2.250	4½	552 000	3.25	439 000
2.500	4	680 000	4.00	540 000
2.750	4	838 000	4.93	666 000
3.000	4	1 010 000	5.97	806 000
3.250	4	1 210 000	7.10	958 000
3.500	4	1 420 000	8.33	1 120 000
3.750	4	1 640 000	9.66	1 300 000
4.000	4	1 880 000	11.08	1 500 000

[a] Values based on 180 ksi for 0.500 and smaller and 170 ksi for 0.625 and larger and stress area in accordance with Footnote *b.*

[b] Stress areas based on Handbook H-28 (U.S. Department of Commerce) as follows:

$$A_s = 0.7854\,[D - (0.9743/n)]^2$$

where:
A_s = stress area,
D = nominal screw size, and
n = threads/in.

[c] Values based on 140 ksi for 0.500 and smaller and 135 ksi for 0.625 and larger and stress area in accordance with Footnote *b.*

TABLE 3
TENSILE REQUIREMENTS FOR FINE THREAD SCREWS

Screw Dia (*D*), in.	Threads/ in.	Tensile Load, min, lbf[a]	Stress Area, in.^{2}[b]	Proof Load (Length Measurement Method), min, lbf[c]
0.060	80	324	0.00180	252
0.073	72	500	0.00278	389
0.086	64	709	0.00394	552
0.099	56	941	0.00523	732
0.112	48	1 190	0.00661	925
0.125	44	1 490	0.00830	1 160
0.138	40	1 830	0.01015	1 420
0.164	36	2 650	0.01474	2 060
0.190	32	3 600	0.0200	2 800
0.250	28	6 500	0.0364	5 100
0.3125	24	10 400	0.0580	8 120
0.375	24	15 800	0.0878	12 300
0.4375	20	21 400	0.1187	16 600
0.500	20	28 800	0.1599	22 400
0.625	18	43 500	0.256	34 600
0.750	16	63 400	0.373	50 400
0.875	14	86 500	0.509	68 700
1.000	12	113 000	0.663	89 500
1.125	12	146 000	0.856	116 000
1.250	12	182 000	1.073	145 000
1.375	12	224 000	1.315	178 000
1.500	12	269 000	1.581	213 000

[a] Values based on 180 ksi for 0.500 and smaller and 170 ksi for 0.625 and larger and stress area in accordance with Footnote *b.*

[b] Stress areas based on H-28 as follows:

$$A_s = 0.7854\,[D - (0.9743/n)]^2$$

where:
A_s = stress area,
D = nominal screw size, and
n = threads/in.

[c] Values based on 140 ksi for 0.500 and smaller and 135 ksi for 0.625 and larger and stress area in accordance with Footnote *b.*

TABLE 4
DECARBURIZATION LIMITS

Threads/in.	Thread Height, h_s	0.75 h_s from Root to Crest, min	0.1 h_s at Root, max
80	0.008	0.006	0.001
72	0.009	0.007	0.001
64	0.010	0.008	0.001
56	0.011	0.008	0.001
48	0.013	0.010	0.001
44	0.014	0.011	0.001
40	0.015	0.011	0.002
36	0.017	0.013	0.002
32	0.019	0.014	0.002
28	0.022	0.017	0.002
24	0.026	0.020	0.003
20	0.031	0.023	0.003
18	0.034	0.026	0.003
16	0.038	0.029	0.004
14	0.044	0.033	0.004
13	0.047	0.035	0.005
12	0.051	0.038	0.005
11	0.056	0.042	0.006
10	0.061	0.046	0.006
9	0.068	0.051	0.007
8	0.077	0.058	0.008
7	0.088	0.066	0.009
6	0.102	0.077	0.010
5	0.123	0.092	0.012
4.5	0.136	0.102	0.014
4	0.153	0.115	0.015

TABLE 5
WEDGE TEST ANGLES

	Wedge Angle, Deg	
Screw Size, *D*, in.	Body Lengths 2*D* or Less or Threaded to the Head	Body Lengths Greater than 2*D*
0.112 to 0.750 incl	6	10
0.875 to 1.500 incl	4	6

SPECIFICATION FOR ULTRASONIC ANGLE-BEAM EXAMINATION OF STEEL PLATES

SA-577/SA-577M

(Identical with ASTM Specification A 577/A 577M-90.) 98

1. Scope

1.1 This specification covers an ultrasonic angle-beam procedure and acceptance standards for the detection of internal discontinuities not laminar in nature and of surface imperfections in a steel plate. This specification is intended for use only as a supplement to specifications which provide straight-beam ultrasonic examination.

NOTE — An internal discontinuity that is laminar in nature is one whose principal plane is parallel to the principal plane of the plate.

1.2 Individuals performing examinations in accordance with this specification shall be qualified and certified in accordance with the requirements of the latest edition of ASNT SNT-TC-1A or an equivalent accepted standard. An equivalent standard is one which covers the qualification and certification of ultrasonic nondestructive examination candidates and which is acceptable to the purchaser.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Document

2.1 *ASNT Standard:*
SNT-TC-1A

3. Ordering Information

3.1 The inquiry and order shall indicate any additions to the provisions of this specification as prescribed in 14.1.

4. Examination Conditions

4.1 The examination shall be conducted in an area free of operations that interfere with proper performance of the examination.

4.2 The surface of the plate shall be conditioned as necessary to provide a clear, easily interpreted trace pattern on the screen. Any specified identification which is removed to achieve proper surface smoothness shall be restored.

5. Apparatus

5.1 The amplitude linearity shall be checked by positioning the transducer over the depth resolution notch in the IIW or similar block so that the signal from the notch is approximately 30% of the screen height, and the signal from one of the back surfaces is approximately 60% of the screen height (two times the height of the signal from the notch). A curve is then plotted showing the deviations from the above established 2:1 ratio that occurs as the amplitude of the signal from the notch is raised in increments of one scale division until the back reflection signal reaches full scale, and then is lowered in increments of one scale division until the notch signal reaches one scale division. At each increment the ratio of the two signals is determined. The ratios are plotted on the graph at

the position corresponding to the larger signal. Between the limits of 20% and 80% of the screen height the ratio shall be within 10% of 2:1. Instrument settings used during inspection shall not cause variation outside the 10% limits established above.

5.2 The search unit shall be a 45-deg (in steel) angle-beam type with active transducer length and width dimensions of a minimum of ½ in. [12.5 mm] and a maximum of 1 in. [25 mm]. Search units of other sizes and angles may be used for additional exploration and evaluation.

6. Examination Frequency

6.1 The ultrasonic frequency selected for the examination shall be the highest frequency that permits detection of the required calibration notch, such that the amplitude of the indication yields a signal-to-noise ratio of at least 3:1.

7. Calibration Reflector

7.1 A calibration notch, the geometry of which has been agreed upon by the purchaser and the manufacturer, with a depth of 3% of the plate thickness, shall be used to calibrate the ultrasonic examination. The notch shall be at least 1 in. [25 mm] long.

7.2 Insert the notch or notches on the surface of the plate so that they are perpendicular to the long axis at a distance of 2 in. [50 mm] or more from the short edge of the plate. Locate the notch not less than 2 in. [50 mm] from the long edges of the plate.

7.3 When the notch cannot be inserted in the plate to be tested, it may be placed in a calibration plate of ultrasonically similar material. The calibration plate will be considered ultrasonically similar if the height of the first back reflection through it is within 25% of that through the plate to be tested at the same instrument calibration. The calibration plate thickness shall be within 1 in. [25 mm] of the thickness of plates to be tested, for plates of 2 in. [50 mm] thickness and greater and within 10% of plates whose thickness is less than 2 in. [50 mm].

7.4 For plate thicknesses greater than 2 in. [50 mm], insert a second calibration notch as described in 7.2, on the opposite side of the plate.

8. Calibration Procedure

8.1 *Plate 2 in.* [50 mm] *and Under in Thickness:*

8.1.1 Place the search unit on the notched surface of the plate with the sound beam directed at the broad side of the notch and position to obtain maximum amplitude from the first vee-path indication which is clearly resolved from the initial pulse. Adjust the instrument gain so that this reflection amplitude is at least 50 but not more than 75% of full screen height. Record the location and amplitude of this indication on the screen.

8.1.2 Move the search unit away from the notch until the second vee-path indication is obtained. Position the search unit for maximum amplitude and record the indication amplitude. Draw a line between the peaks from the two successive notch indications on the screen. This line is the distance amplitude curve (DAC) for this material and shall be a 100% reference line for reporting indication amplitudes.

8.2 *Plate Over 2 to 6 in.* [50 to 150 mm] *Inclusive in Thickness:*

8.2.1 Place the search unit on the test surface aimed at the broad side of the notch on the opposite surface of the plate. Position the search unit to obtain a maximum one-half vee-path indication amplitude. Adjust the instrument gain so that this amplitude is at least 50% but not more than 80% of full screen height. Record the location and amplitude on the screen. Without adjusting the instrument settings, repeat this procedure for the 1½ vee-path indication.

8.2.2 Without adjusting the instrument settings, reposition the search unit to obtain a maximum full vee-path indication from the notch on the test surface. Record the location and amplitude on the screen.

8.2.3 Draw a line on the screen connecting the points established in 8.2.1 and 8.2.2. This curve shall be a DAC for reporting indication amplitudes.

8.3 *Plate over 6 in.* [150 mm] *in Thickness:*

8.3.1 Place the search unit on the test surface aimed at the broad side of the notch on the opposite surface of the plate. Position the search unit to obtain a maximum one-half vee-path indication amplitude. Adjust the instrument gain so that this amplitude is at least 50% but not more than 80% of full screen height. Record the location and amplitude on the screen.

8.3.2 Without adjusting the instrument settings, reposition the search unit to obtain a maximum full

vee-path indication from the notch on the test surface. Record the location and amplitude on the screen.

8.3.3 Draw a line on the screen connecting the points established in 8.3.1 and 8.3.2. This line shall be a DAC for reporting indication amplitudes.

9. Examination Procedure

9.1 Scan one major surface of the plate on grid lines perpendicular and parallel to the major rolling direction. Grid lines shall be on 9 in. [225 mm] centers. Use a suitable couplant such as water, oil, or glycerin. Scan by placing the search unit near one edge with the ultrasonic beam directed toward the same edge and move the search unit along the grid line in a direction perpendicular to the edge to a location two plate thicknesses beyond the plate center. Repeat this scanning procedure on all grid lines from each of the four edges.

9.2 Measure grid lines from the center or one corner of the plate.

9.3 Position the search unit to obtain a maximum indication amplitude from each observed discontinuity.

9.4 For each discontinuity indication that equals or exceeds the DAC, record the location and length, and the amplitude to the nearest 25%. No indication with an amplitude less than the DAC shall be recorded.

9.5 At each recorded discontinuity location, conduct a 100% examination of the mass under a 9 in. [225 mm] square which has the recorded discontinuity position at its center. Conduct the examination in directions perpendicular and parallel to the major rolling direction.

10. Acceptance Standard

10.1 Any discontinuity indication that equals or exceeds the DAC shall be considered unacceptable unless additional exploration by the longitudinal method indicates it is laminar in nature.

11. Rehearing

11.1 The manufacturer reserves the right to discuss unacceptable ultrasonically examined plate with the purchaser with the object of possible repair of the ultrasonically indicated discontinuity before rejection of the plate.

12. Inspection

12.1 The purchaser's representative shall have access, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the ultrasonic examination of the material ordered. The manufacturer shall afford the representative all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All examinations and verifications shall be so conducted as not to interfere unnecessarily with the manufacturer's operations.

13. Marking

13.1 Plates accepted in accordance with this specification shall be identified by metal stamping or stencilling "UT A 577" in one corner of the plate, at a location within 6 in. [150 mm] of the heat number.

14. Report

14.1 Unless otherwise agreed upon between the purchaser and manufacturer, the manufacturer shall report the following data:

14.1.1 Plate identity including pin-pointed recordable indication locations, lengths, and amplitudes.

14.1.2 Examination parameters, including: couplant; search unit type, angle, frequency, and size; instrument make, model, and serial number; and calibration plate description.

14.1.3 Date of examination and name of operator.

SPECIFICATION FOR STRAIGHT-BEAM ULTRASONIC EXAMINATION OF PLAIN AND CLAD STEEL PLATES FOR SPECIAL APPLICATIONS

SA-578/SA-578M

(Identical with ASTM Specification A 578/A 578M-96) 98

1. Scope

1.1 This specification covers the procedure and acceptance standards for straight-beam, pulse-echo, ultrasonic examination of rolled carbon and alloy plain and clad steel plates, $\frac{3}{8}$ in. [10 mm] in thickness and over, for special applications. The method will detect internal discontinuities parallel to the rolled surfaces. Three levels of acceptance standards are provided. Supplementary requirements are provided for examination of clad plate and for alternative procedures.

1.2 Individuals performing examinations in accordance with this specification shall be qualified and certified in accordance with the requirements of the latest edition of ASNT SNT-TC-1A or an equivalent accepted standard. An equivalent standard is one which covers the qualification and certification of ultrasonic nondestructive examination candidates and which is acceptable to the purchaser.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in noncomformance with the specification.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 263 Specification for Corrosion-Resisting Chromium Steel Clad Plate, Sheet, and Strip

A 264 Specification for Stainless Chromium-Nickel Steel Clad Plate, Sheet, and Strip

A 265 Specification for Nickel and Nickel-Base Alloy Clad Steel Plate

2.2 *ANSI Standard:*

B 46.1 Surface Texture

2.3 *ASNT Standard:*

SNT-TC-1A

3. Ordering Information

3.1 The inquiry and order shall indicate the following:

3.1.1 Acceptance level requirements (Sections 7, 8 and 9). Acceptance Level B shall apply unless otherwise agreed to by purchaser and manufacturer.

3.1.2 Any additions to the provisions of this specification as prescribed in 5.2, 12.1, and Section 13.

3.1.3 Supplementary requirements, if any.

4. Apparatus

4.1 The amplitude linearity shall be checked by positioning the transducer over the depth resolution notch in the IIW or similar block so that the signal from the notch is approximately 30% of the screen height, and the signal from one of the back surfaces is approximately 60% of the screen height (two times the height of the signal from the notch). A curve is then plotted showing the deviations from the above established 2:1 ratio that occurs as the amplitude of the signal from the notch is raised in increments of one scale division until the back reflection signal reaches full scale, and then is lowered in increments of one scale division until the notch signal reaches one scale division. At each increment the ratio of the two signals is determined. The ratios are plotted on the graph at the position corresponding to the larger signal. Between the limits of 20% and 80% of the screen height, the ratio shall be within 10% of 2:1. Instrument settings used during inspection shall not cause variation outside the 10% limits established above.

4.2 The transducer shall be 1 or $1\frac{1}{8}$ in. [25 or 30 mm] in diameter or 1 in. [25 mm] square.

4.3 Other search units may be used for evaluating and pinpointing indications.

5. Procedure

5.1 Perform the inspection in an area free of operations that interfere with proper performance of the test.

5.2 Unless otherwise specified, make the ultrasonic examination on either major surface of the plate.

5.3 The plate surface shall be sufficiently clean and smooth to maintain a first reflection from the opposite side of the plate at least 50% of full scale during scanning. This may involve suitable means of scale removal at the manufacturer's option. Condition local rough surfaces by grinding. Restore any specified identification which is removed when grinding to achieve proper surface smoothness.

5.4 Perform the test by one of the following methods: direct contact, immersion, or liquid column coupling. Use a suitable couplant such as water, soluble oil, or glycerin. As a result of the test by this method, the surface of plates may be expected to have a residue of oil or rust, or both.

5.5 A nominal test frequency of $2\frac{1}{4}$ MHz is recommended. When testing plates less than $\frac{3}{4}$ in. [20 mm] thick a frequency of 5 MHz may be necessary. Thickness, grain size or microstructure of the material and nature of the equipment or method may require a higher or lower test frequency. Use the transducers at their rated frequency. A clean, easily interpreted trace pattern should be produced during the examination.

5.6 *Scanning:*

5.6.1. Scanning shall be along continuous perpendicular grid lines on nominal 9 in. [225 mm] centers, or at the option of the manufacturer, shall be along continuous parallel paths, transverse to the major plate axis, on nominal 4 in. [100 mm] centers, or shall be along continuous parallel paths parallel to the major plate axis, on 3 in. [75 mm] or smaller centers. Measure the lines from the center or one corner of the plate with an additional path within 2 in. [50 mm] of all edges of the plate on the searching surface.

5.6.2 Conduct the general scanning with an instrument adjustment that will produce a first reflection from the opposite side of a sound area of the plate from 50% to 90% of full scale. Minor sensitivity adjustments may be made to accommodate for surface roughness.

5.6.3 When a discontinuity condition is observed during general scanning adjust the instrument to produce a first reflection from the opposite side of a sound area of the plate of 75 ± 5% of full scale. Maintain this instrument setting during evaluation of the discontinuity condition.

6. Recording

6.1 Record all discontinuities causing complete-loss of back reflection.

6.2 For plates $\frac{3}{4}$ in. [20 mm] thick and over, record all indications with amplitudes equal to or greater than 50% of the initial back reflection and accompanied by a 50% loss of back reflection.

NOTE 2 — Indications occurring midway between the initial pulse and the first back reflection may cause a second reflection at the location of the first back reflection. When this condition is observed it shall be investigated additionally by use of multiple back reflections.

6.3 Where grid scanning is performed and recordable conditions as in 6.1 and 6.2 are detected along a given grid line, the entire surface area of the squares adjacent to this indication shall be scanned. Where parallel path scanning is performed and recordable conditions as in 6.1 and 6.2 are detected, the entire surface area of a 9 by 9 in. [225 by 225 mm] square centered on this indication shall be scanned. The true boundaries where

these conditions exist shall be established in either method by the following technique: Move the transducer away from the center of the discontinuity until the height of the back reflection and discontinuity indications are equal. Mark the plate at a point equivalent to the center of the transducer. Repeat the operation to establish the boundary.

7. Acceptance Standard — Level A

7.1 Any area where one or more discontinuities produce a continuous total loss of back reflection accompanied by continous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. [75 mm] or ½ of the plate thickness, whichever is greater, is unacceptable.

8. Acceptance Standards — Level B

8.1 Any area where one or more discontinuities produce a continuous total loss of back reflection accompanied by continuous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. [75 mm] or ½ of the plate thickness, whichever is greater, is unacceptable.

8.2 In addition, two or more discontinuities smaller than described in 8.1 shall be unacceptable unless separated by a minimum distance equal to the greatest diameter of the larger discontinuity or unless they may be collectively encompassed by the circle described in 8.1.

9. Acceptance Standard — Level C

9.1 Any area where one or more discontinuities produce a continuous total loss of back reflection accompanied by continuous indications on the same plane that cannot be encompassed within a 1 in. [25 mm diameter circle is unacceptable.

10. Rehearing

10.1 The manufacturer reserves the right to discuss rejectable ultrasonically tested plate with the purchaser with the object of possible repair of the ultrasonically indicated defect before rejection of the plate.

11. Inspection

11.1 The inspector representing the purchaser shall have access at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the ultrasonic testing of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted without interfering unnecessarily with the manufacturer's operations.

12. Marking

12.1 Plates accepted according to this specification shall be identified by stenciling (stamping) "UT A 578 — A" on one corner for Level A and "UT A 578 — B" for Level B, and ''UT A 578—C'' for Level C. The supplement number shall be added for each supplementary requirement ordered.

13. Report

13.1 Unless otherwise agreed to by the purchaser and the manufacturer, the manufacturer shall report the following data:

13.1.1 All recordable indications listed in Section 6 on a sketch of the plate with sufficient data to relate the geometry and identity of the sketch to those of the plate.

13.1.2 Test parameters including: Make and model of instrument, test frequency, surface condition, transducer (type and frequency), and couplant.

13.1.3 Date of test.

14. Keywords

14.1 nondestructive testing; pressure containing parts; pressure vessel steels; steel plate for pressure vessel applications; steel plates; ultrasonic examinations

SUPPLEMENTARY REQUIREMENTS

These supplementary requirements shall apply only when individually specified by the purchaser. When details of these requirements are not covered herein, they are subject to agreement between the manufacturer and the purchaser.

S1. Scanning

S1.1 Scanning shall be continuous over 100% of the plate surface.

S2. Acceptance Standard

S2.1 Any recordable condition listed in Section 6 that (1) is continuous, (2) is on the same plane (within 5% of the plate thickness), and (3) cannot be encompassed by a 3 in. [75 mm] diameter circle, is unacceptable. Two or more recordable conditions (see Section 5), that (1) are on the same plane (within 5% of plate thickness), (2) individually can be encompassed by a 3 in. [75 mm] diameter circle, (3) are separated from each other by a distance less than the greatest dimension of the smaller indication, and (4) collectively cannot be encompassed by a 3 in. [75 mm] diameter circle, are unacceptable.

S2.2 An acceptance level more restrictive than Sections 7 or 8 shall be used by agreement between the manufacturer and purchaser.

S3. Procedure

S3.1 The manufacturer shall provide a written procedure in accordance with this specification.

S4. Certification

S4.1 The manufacturer shall provide a written certification of the ultrasonic test operator's qualifications.

S5. Surface Finish

S5.1 The surface finish of the plate shall be conditioned to a maximum 125 μin. [3 μm] AA (see ANSI B46.1) prior to test.

S6. Examination of Integrally Bonded Clad Plate, Acceptance Level S6

S6.1 Examine the plate from the clad surface using procedures and techniques in accordance with this specification.

S6.2 Inspect the backing steel to Level B, or, if specifically requested by customer, to Level A, or Level C.

S6.3 The cladding shall be interpreted to be unbonded when there is complete loss of back reflection accompanied by an echo indication from the plane of the interface of the clad and backing steel.

S6.4 Unless otherwise specified, indications of unbond determined in accordance with S6.3 that cannot be encompassed within a 3 in. [75 mm] diameter circle shall be weld repaired subject to the requirements and limitations for the repair of defects in cladding of the appropriate material specification.

S6.5 This supplementary requirement is applicable to Specifications A 263, A 264, and A 265.

S7. Examination of Integrally Bonded Clad Plate, Acceptance Level S7

S7.1 The plate shall be examined from the clad surface using procedures and techniques according to this specification except 100% surface search is mandatory.

S7.2 Inspect the backing steel to Level B, or, if specifically requested by customer, to Level A, or Level C.

S7.3 The cladding shall be interpreted to be unbonded when there is complete loss of back reflection accompanied by an echo indication from the plane of the interface of the clad and backing steel.

S7.4 Unless otherwise specified, indications of unbond determined in accordance with S7.3 that cannot be encompassed within a 1 in. [25 mm] diameter circle shall be weld repaired subject to the requirements and

limitations for the repair of defects in cladding of the appropriate material specification. Additionally, prior approval must be obtained if the weld repaired surface exceeds 1.5% of the cladding surface.

S7.5 This supplementary requirement is applicable to Specification A 263, A 264, and A 265.

S8. Ultrasonic Examination Using Flat Bottom Hole Calibration (for Plates 4 in. [100 mm] Thick and Greater)

S8.1 Use the following calibration and recording procedures in place of 5.6.2, 5.6.3, and Section 6.

S8.2 The transducer shall be in accordance with 4.2.

S8.3 *Reference Reflectors* — The *T*/4, *T*/2, and 3*T*/4 deep flat bottom holes shall be used to calibrate the equipment. The flat bottom hole diameter shall be in accordance with Table S8.1. The holes may be drilled in the plate to be examined if they can be located without interfering with the use of the plate, in a prolongation of the plate to be examined, or in a reference block of the same nominal composition, and thermal treatment as the plate to be examined. The surface of the reference block shall be no better to the unaided eye than the plate surface to be examined. The reference block shall be of the same nominal thickness (within 75 to 125% or 1 in. [25 mm] of the examined plate, whichever is less) and shall have acoustical properties similar to the examined plate. Acoustical similarity is presumed when, without a change in instrument setting, comparison of the back reflection signals between the reference block and the examined plate shows a variation of 25% or less.

S8.4 *Calibration Procedure:*

S8.4.1 Couple and position the search unit for maximum amplitudes from the reflectors at *T*/4, *T*/2, and 3*T*/4. Set the instrument to produce a 75 ± 5% of full scale indication from the reflector giving the highest amplitude.

S8.4.2 Without changing the instrument setting, couple and position the search unit over each of the holes and mark on the screen the maximum amplitude from each hole and each minimum remaining back reflection.

S8.4.3 Mark on the screen half the vertical distance from the sweep line to each maximum amplitude hole mark. Connect the maximum amplitude hole marks and extend the line through the thickness for the 100% DAC (distance amplitude correction curve). Similarly connect and extend the half maximum amplitude marks for the 50% DAC.

S8.5 *Recording:*

S8.5.1 Record all areas where the remaining back reflection is smaller than the highest of the minimum remaining back reflections found in S8.4.2.

S8.5.2 Record all areas where indications exceed 50% DAC.

S8.5.3 Where recordable conditions listed in S8.5.1 and S8.5.2 are detected along a given grid line, continuously scan the entire surface area of the squares adjacent to the condition and record the boundaries or extent of each recordable condition.

S8.6 Scanning shall be in accordance with 5.6.

S8.7 The acceptance levels of Section 7 or 8 shall apply as specified by the purchaser except that the recordable condition shall be as given in S8.5.

S9. Ultrasonic Examination of Electroslag Remelted (ESR) and Vacuum-Arc Remelted (VAR) Plates, from 1 to 16 in. [25 to 400 mm] in Thickness, Using Flat-Bottom Hole Calibration and Distance-Amplitude Corrections

S9.1 The material to be examined must have a surface finish of 200 μin. [5 μm] as maximum for plates up to 8 in. [200 mm] thick, inclusive, and 250 μin. [6 μm] as maximum for plates over 8 to 16 in. [200 to 400 mm] thick.

S9.2 Use the following procedures in place of 5.6.1, 5.6.2, 5.6.3, and Section 6.

S9.3 The transducer shall be in accordance with 4.2.

S9.4 *Reference Reflectors* — The *T*/4, *T*/2, and 3*T*/4 deep flat bottom holes shall be used to calibrate the equipment. The flat bottom hole diameter shall be in accordance with Table S9.1. The flat bottoms of the holes shall be within 1° of parallel to the examination surface. The holes may be drilled in the plate to be examined if they can be located without interfering with the use of the plate, in a prolongation of the plate to be examined, or in a reference block of the same nominal composition and thermal treatment as the plate to be examined. The surface of the reference block shall be no better to the unaided eye than the plate surface to be examined. The reference block shall be of the same nominal thickness (within 75 to 125% or 1 in. [25 mm] of the examined plate, whichever is

less) and shall have acoustical properties similar to the examined plate. Acoustical similarity is presumed when, without a change in instrument setting, comparison of the back reflection signals between the reference block and examined plate shows a variation of 25% or less.

S9.5 *Calibration Procedure:*

S9.5.1 Couple and position the search unit for maximum amplitudes from the reflectors at *T*/4, *T*/2, and 3*T*/4. Set the instrument to produce a 75 ± 5% of full-scale indication from the reflector giving the highest amplitude.

S9.5.2 Without changing the instrument setting, couple and position the search unit over each of the holes and mark on the screen the maximum amplitude from each of the holes.

S9.5.3 Mark on the screen half the vertical distances from the sweep line to each maximum amplitude hole mark. Connect the maximum amplitude hole marks and extend the line through the thickness for the 100% DAC (distance amplitude correction curve). Similarly connect and extend the half maximum amplitude marks for the 50% DAC.

S9.6 *Scanning* — Scanning shall cover 100% of one major plate surface, with the search unit being indexed between each pass such that there is at least 15% overlap of adjoining passes in order to assure adequate coverage for locating discontinuities.

S9.7 *Recording* — Record all areas where the back reflection drops below the 50% DAC. If the drop in back reflection is not accompanied by other indications on the screen, recondition the surface in the area and reexamine ultrasonically. If the back reflection is still below 50% DAC, the loss may be due to the metallurgical structure of the material being examined. The material shall be held for metallurgical review by the purchaser and manufacturer.

S9.8 *Acceptance Standards* — Any indication that exceeds the 100% DAC shall be considered unacceptable. The manufacturer may reserve the right to discuss rejectable ultrasonically examined material with the purchaser, the object being the possible repair of the ultrasonically indicated defect before rejection of the plate.

TABLE S8.1
CALIBRATION HOLE DIAMETER AS A FUNCTION OF PLATE THICKNESS (S8)

	4–6	>6–9	>9–12	>12–20
Plate Thickness, in. [mm]	[100–150]	[>150–225]	[>225–300]	[>300–500]
Hole Diameter, in. [mm]	5/8 [16]	3/4 [19]	7/8 [22]	1 1/8 [29]

TABLE S9.1
CALIBRATION HOLE DIAMETER AS A FUNCTION OF PLATE THICKNESS (S9)

	1–4	>4–8	>8–12	>12–16
Plate Thickness, in. [mm]	[25–100]	[>100–200]	[>200–300]	[>300–400]
Hole Diameter, in. [mm]	1/8 [3]	1/4 [6]	3/8 [10]	1/2 [13]

SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED LOW-CARBON STEEL PIPE FOR THE CHEMICAL INDUSTRY 98

SA-587

(Identical with ASTM Specification A 587-93 except for the deletion of 1.5.) 98

1. Scope

1.1 This specification covers electric-resistance-welded low-carbon steel pipe intended for use as process lines.

1.2 Pipe ordered under this specification shall be suitable for severe forming operations involving flanging in all sizes and bending to close radii up to and including NPS 4.

1.3 This specification covers NPS ½ through 10, plus additional sizes. The corresponding outside diameters and wall thicknesses for NPS ½ through 10 are listed in Table 4, as are the dimensions for the additional sizes.

NOTE—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.4 The values stated in inch–pound units are to be regarded as the standard.

1.5 DELETED

2. Referenced Documents

2.1 *ASTM Standards:*

A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 213 Practice for Ultrasonic Inspection of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

3. Ordering Information

3.1 Orders for material under this specification should include the following as required to describe the desired material adequately:

3.1.1 Quantity (feet or number of pieces),

3.1.2 Name of material (electric-resistance-welded steel pipe),

3.1.3 Size (NPS or outside diameter and wall thickness),

3.1.4 Length (definite cut length or random),

3.1.5 Test report required (see 14.2),

3.1.6 Specification number, and

3.1.7 Special requirements.

4. Materials and Manufacture

4.1 *Process* — The steel shall be aluminum killed steel made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 *Manufacture* — The pipe shall be made by electric resistance welding.

4.4 *Heat Treatment* — Pipe furnished in the as-welded condition shall be normalized at a temperature above the upper critical temperature. Cold-drawn pipe shall be normalized after the final cold-draw pass.

5. Chemical Composition

5.1 *Heat Analysis* — An analysis of each heat of steel shall be made to determine the percentages of the elements specified. The chemical composition thus determined shall conform to the requirements specified in Table 1 and the chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

5.2 *Product Analysis* — When requested on the purchase order, a product analysis shall be made by the supplier from one pipe or coil of steel per heat. The chemical composition thus determined shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Table 1.

5.3 *Retests* — If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or pipe shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise, all remaining material in the heat shall be rejected or, at the option of the producer, each length of flat-rolled stock or pipe may be individually tested for acceptance. Lengths of flat-rolled stock or pipe which do not meet the requirements of the specification shall be rejected.

5.4 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in Table 1 is not permitted.

6. Mechanical Requirements

6.1 *Tensile Properties:*

6.1.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2.

6.1.2 The yield strength shall be determined by the drop of the beam, by the halt in the gage of the testing machine, by the use of dividers, or by other approved methods. When a definite yield point is not exhibited, the yield strength corresponding to a permanent offset of 0.2% of the gage length of the specimen, or to a total extension of 0.5% of the gage length under load, shall be determined.

6.1.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. (19 mm) from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

6.2 *Flattening Test:*

6.2.1 A section of pipe not less than 4 in. (102 mm) in length shall be flattened cold between parallel plates in two steps. The weld shall be placed 90° from the direction of the applied force. During the first step, which is a test for ductility, no cracks or breaks, except as provided for in 6.2.5, shall occur on the inside or outside surfaces until the distance between the plates is less than the value of H, calculated by the following equation:

$$H = [(1 + e)t]/[e + t/D]$$

where:

H = distance between flattening plates, in.,
t = specified wall thickness of the pipe, in.,
D = specified outside diameter of the pipe, in., and
e = deformation per unit length (0.09 for low-carbon steel).

6.2.2 During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

6.2.3 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

6.2.4 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

6.2.5 When low *D*-to-*t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than 10.

6.3 *Reverse Flattening Test* — A section 4 in. (102 mm) in length of pipe in sizes down to and including $^{13}/_{16}$ in. (20.6 mm) in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

6.4 *Flange Test* — A section of pipe not less than 4 in. (102 mm) in length shall be capable of having a flange turned over at a right angle to the body of the pipe without cracking or showing flaws. This flange, as measured from the outside of the pipe, shall be not less than $\frac{1}{8}$ in. (3.2 mm) nor more than $\frac{1}{2}$ in. (12.7 mm). Within these limits, the width of the flange shall be not less than the percentages specified in Table 3.

7. Dimensions and Permissible Variations

7.1 *Permissible Variations in Outside Diameter and Wall Thickness* — The outside diameter and wall thickness variations shall not exceed the limits prescribed in Table 4.

7.2 *Permissible Variations in Straightness* — Each pipe shall be straight within 0.030 in. (0.76 mm) maximum deflection in any 3 ft (0.91 m) length to 8 NPS. For 8 NPS and above, pipe shall be straight within 0.060 in. (1.52 mm) maximum deflection in any 3 ft (0.91 m) length. Galvanized pipe shall be reasonably straight.

7.3 *Lengths:*

7.3.1 Pipe may be ordered in definite cut lengths or in random lengths as provided herein.

7.3.2 When ordered in definite cut lengths, the variation in length shall not exceed the amounts prescribed in Table 5.

7.3.3 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft (4.9 to 6.7 m) with 5% 12 to 16 ft (3.7 to 4.9 m), or in double random lengths with a minimum average of 35 ft (10.7 m) and a minimum length of 22 ft (6.7 m) with 5% 16 to 22 ft (4.9 to 6.7 m).

8. Workmanship, Finish, and Appearance

8.1 The finished pipe shall be free of injurious defects and shall have a workman-like finish. Minor defects may be removed by grinding, provided the wall thickness is not reduced to less than the minimum thickness permitted for the ordered nominal wall thickness.

8.2 The pipe shall have smooth ends free of burrs and free of scale except that the pipe may have a superficial "blue" oxide film on the surfaces.

8.3 For NPS $\frac{1}{2}$ to $1\frac{1}{2}$ inclusive, the inside diameter welding flash shall be removed so that the remaining flash does not exceed 0.006 in. (0.15 mm). For NPS over $1\frac{1}{2}$, the remaining inside diameter welding flash shall not exceed 0.010 in. (0.25 mm).

8.4 For all nominal sizes, the outside diameter welding flash shall be removed flush with the outside diameter contour.

8.5 Undercut flash must be smoothly blended into the pipe wall.

8.6 The intent of the flash conditions as prescribed in 8.3, 8.4, and 8.5 is to obtain a surface contour suitable for flanging.

9. Number of Tests

9.1 Two tensile tests as specified in 6.1 shall be made from each heat.

9.2 The flattening test as specified in 6.2 shall be made on two lengths of pipe from each lot of 250 lengths or fraction thereof.

9.3 The reverse flattening test specified in 6.3 shall be made on one length of pipe from each lot of 250 lengths or fraction thereof.

9.4 The flange test as specified in 6.4 shall be made on specimens from two lengths of pipe from each lot of 250 lengths or fraction thereof.

10. Retests

10.1 If the results of the mechanical tests of any heat or lot do not conform to the requirements specified, retests may be made on additional pipe of double the original number from the same heat or lot, each of which shall conform to the requirements specified.

11. Retreatment

11.1 If a heat or lot fails to conform to the test requirements, that heat or lot may be reheat treated and resubmitted for tests. Not more than one reheat treatment shall be permitted.

12. Test Specimens and Methods of Testing

12.1 The test specimens and the tests required by this specification shall conform to those described in Test Methods and Definitions A 370.

12.2 Test specimens shall be taken from the ends of finished pipe prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws.

12.3 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

13. Nondestructive Test

13.1 The nondestructive test shall be made instead of the hydrostatic test.

13.1.1 The test shall provide a 360° inspection for sizes up to and including 3½ in. (88.9 mm) outside diameter.

13.1.2 For pipe larger than 3½ in. (88.9 mm) outside diameter, nondestructive inspection of the weld and heat affected zone is required.

13.2 Each pipe shall be tested with a nondestructive test in accordance with Practices E 213, E 273, E 309, or E 570. Except as provided in 13.6.2, it is the intent of this test to reject pipe with imperfections that produce test signals equal to or greater than that of the calibration standard. In order to accommodate the various types of nondestructive testing equipment and techniques in use, and manufacturing practices employed, any one of the following calibration standards may be used, at the option of the producer, to establish a minimum sensitivity level for rejection:

13.3 For eddy-current testing, the calibration pipe shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection. For welded pipe, they shall be placed in the weld if visible.

13.3.1 *Drilled Hole* — A hole not larger than 0.031 in. (0.79 mm) in diameter shall be drilled radially and completely through the pipe wall, taking care to avoid distortion of the pipe while drilling.

13.3.2 *Transverse Tangential Notch* — Using a round tool or file with a ¼ in. (6.4 mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe, preferably in the weld area. Said notch shall have a depth not exceeding 12½% of the specified wall thickness of the pipe or 0.004 in. (0.10 mm), whichever is greater.

13.3.3 *Longitudinal Notch* — A notch 0.031 in. (0.79 mm) or less in width shall be machined in a radial plane parallel to the pipe axis on the outside surface of the pipe, to a depth not exceeding 12½% of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

13.4 For ultrasonic testing, the longitudinal calibration reference notches shall be at the option of the producer, any one of the three common notch shapes shown in Practices E 213 or E 273. The depth of the notch shall not exceed 12½% of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater. For welded pipe, the notch shall be placed in the weld, if visible.

13.5 For flux leakage testing, each of the longitudinal calibration notches shall be a straight sided notch not over 12½% of the wall thickness in depth and not over 1.0 in. (25 mm) in length. Both outside diameter and inside diameter notches shall be placed in the tube located sufficiently apart to enable separation and identification of the signals.

13.6 Pipe producing a signal equal to or greater than the calibration defect shall be subject to rejection. The area producing the signal may be examined.

13.6.1 Test signals produced by imperfections that cannot be identified, or produced by cracks or crack-like defects shall result in rejection of the pipe subject to rework and retest.

13.6.2 Test signals produced by imperfections such as those listed below may be judged as injurious or noninjurious depending on visual observation or their severity or the type of signal they produce on the testing equipment used, or both:

13.6.2.1 Dinges,

13.6.2.2 Straightener marks,

13.6.2.3 Loose inside diameter bead and cutting chips,

13.6.2.4 Scratches,

13.6.2.5 Steel die stamps,

13.6.2.6 Chattered flash trim,

13.6.2.7 Stop marks, or

13.6.2.8 Tube reducer ripple.

13.6.3 Any imperfection of the above type exceeding 0.004 in. (0.102 mm) or 12½% of the specified wall thickness (whichever is greater) in depth shall be considered injurious.

13.6.3.1 If the imperfection is judged as injurious, the pipe shall be rejected but may be reconditioned and retested providing the dimensional requirements are met.

13.6.3.2 If the imperfection is explored to the extent that it can be identified as noninjurious, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

14. Inspection

14.1 The inspector shall have entry at all times while work on an order is being done to all parts of the manufacturer's works that concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All tests and inspection shall be made prior to shipment.

14.2 When inspection at the place of manufacture has been waived by the customer, the manufacturer shall furnish a statement that the material has been tested and has met all the requirements of this specification. A certificate or report shall be made available to the customer when all the requirements of this specification have been met. When Supplementary Requirement S1 is furnished, certificates or reports furnished shall bear the notation "S-1."

15. Rejection

15.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

15.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

16. Product Marking

16.1 Each length of pipe NPS 1½ and larger shall be legibly marked by either stenciling or stenciling and light die marking. The die marking shall include the manufacturer's logo or symbol and the stenciling shall include the name or brand of the manufacturer, size, heat number, and the specification number. Such marking shall be applied starting within 8 in. (203 mm) of the end of each length.

16.2 For NPS under 1½, the markings prescribed in 16.1 may be applied to tags and securely attached to the bundle, bale, or other unit, prepared for shipment.

16.3 A tag shall be securely attached to each bundle of pipe shipped indicating the name of the manufacturer, size, wall thickness, length, and specification.

16.4 *Bar Coding* — In addition to the requirements in 16.1, 16.2, and 16.3, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team. **98**

17. Packaging

17.1 The manufacturer, at his option, will box, crate, carton, or package in secured lifts, or bundle to ensure safe delivery. Special packaging requiring extra operations other than those normally used by the manufacturer must be specified on the order.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS

Element	Composition, %
Carbon, max	0.15
Manganese	0.27–0.63
Phosphorus, max	0.035
Sulfur, max	0.035
Aluminum	0.02–0.100

TABLE 2
TENSILE REQUIREMENTS

Tensile strength, min, psi (MPa)	48 000 (331)
Yield strength, min, psi (MPa)	30 000 (207)
Elongation in. 2 in. or 50 mm, min, %	40

TABLE 3
FLANGE REQUIREMENTS

Outside Diameter of Pipe, in.	Width of Flange, % of OD
Over $\frac{3}{4}$ to $2\frac{1}{2}$, incl	15
Over $2\frac{1}{2}$ to $3\frac{3}{4}$, incl	$12\frac{1}{2}$
Over $3\frac{3}{4}$ to $4\frac{1}{2}$, incl	10
Over $4\frac{1}{2}$ to $6\frac{5}{8}$, incl	$7\frac{1}{2}$
Over $6\frac{5}{8}$	5

TABLE 4
TOLERANCE FOR OUTSIDE DIAMETER AND WALL THICKNESS

NPS Designator	Outside Diameter	Wall Thickness					
		Min	Nom	Max	Min	Nom	Max
		Inches					
—	0.8125 ± 0.004	0.095	0.103	0.111	0.129	0.140	0.151
1/2	0.840 ± 0.006	0.095	0.103	0.111	0.125	0.140	0.151
3/4	1.050 ± 0.006	0.099	0.108	0.117	0.135	0.147	0.159
—	1.0625 ± 0.006	0.099	0.108	0.117	0.135	0.147	0.159
—	1.3125 ± 0.006	0.116	0.126	0.136	0.157	0.171	0.185
1	1.315 ± 0.006	0.116	0.126	0.136	0.157	0.171	0.185
1 1/4	1.660 ± 0.007	0.121	0.132	0.143	0.167	0.182	0.197
—	1.875 ± 0.008	0.127	0.138	0.149	0.175	0.190	0.205
1 1/2	1.900 ± 0.008	0.127	0.158	0.149	0.175	0.190	0.205
2	2.375 ± 0.010	0.135	0.147	0.159	0.191	0.208	0.225
3	3.500 ± 0.015	0.189	0.206	0.223	0.262	0.286	0.310
4	4.500 ± 0.017	0.207	0.226	0.245	0.295	0.322	0.349
6	6.625 ± .030	0.245	0.267	0.289	0.378	0.412	0.446
8	8.625 ± .040	0.282	0.308	0.334	0.438	0.478	0.518
10	10.750 ± .050	0.319	0.348	0.377	0.520	0.567	0.614
		Millimetres					
—	20.64 ± 0.10	2.41	2.62	2.82	3.28	3.56	3.84
1/2	21.30 ± 0.15	2.41	2.62	2.82	3.28	3.56	3.84
3/4	26.70 ± 0.15	2.51	2.74	2.97	3.43	3.73	4.04
—	26.99 ± 0.15	2.51	2.74	2.97	3.43	3.73	4.04
—	33.34 ± 0.15	2.95	3.20	3.45	3.99	4.34	4.70
1	33.40 ± 0.15	2.95	3.20	3.45	3.99	4.34	4.70
1 1/4	42.16 ± 0.18	3.07	3.35	3.63	4.24	4.62	5.00
—	47.63 ± 0.20	3.22	3.51	3.78	4.45	4.83	5.21
1 1/2	48.30 ± 0.020	3.22	3.51	3.78	4.45	4.83	5.21
2	60.33 ± 0.25	3.43	3.73	4.04	4.85	5.28	5.72
3	88.90 ± 0.38	4.80	5.23	5.66	6.66	7.26	7.87
4	114.30 ± 0.43	5.26	5.74	6.22	7.49	8.18	8.87
6	168.28 ± 0.76	6.22	9.32	7.34	9.60	10.47	11.33
8	219.08 ± 1.02	7.16	7.82	8.48	11.13	12.14	13.16
10	273.05 ± 1.27	8.10	8.84	9.58	13.21	14.40	15.60

TABLE 5
PERMISSIBLE VARIATIONS IN LENGTH[A]

Outside Diameter, in.	Cut Length, in. (mm)	
	Over	Under
Under 2	1/8 (3.2)	0
2 and over	3/16 (4.8)	0

[A] These permissible variations in length apply to pipe before bending. They apply to cut lengths up to and including 24 ft (7.3 m). For lengths over 24 ft, an additional over-tolerance of 1/8 in. for each 10 ft (3.0 m) or fraction thereof shall be permissible, up to a maximum of 1/2 in. (12.7 mm).

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below may be included in the purchaser's order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirements details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S1. Hydrostatic Testing

S1.1 Hydrostatic testing shall be in accordance with Specification A 530/A 530M. When this supplement is furnished the pipe shall be marked "S-1."

S2. Galvanizing

S2.1 Galvanizing shall be in accordance with Specification A 53, except that the rate of application shall be 1.3 minimum to 1.7 maximum oz per f^2.

S3. Surface Coatings

S3.1 All surfaces shall be coated; the exterior with a hard drying lacquer, and the interior with a suitable rust inhibitor.

SPECIFICATION FOR HIGH-STRENGTH QUENCHED AND TEMPERED LOW-ALLOY STEEL FORGED FITTINGS AND PARTS FOR PRESSURE VESSELS

SA-592/SA-592M

(Identical with ASTM Specification A 592/A 592M-89 (R 1994)$^{\epsilon 1}$.) 98

1. Scope

1.1 This specification covers high-strength quenched and tempered low-alloy steel forged fittings and parts for pressure vessels. The maximum thickness of forgings under this specification shall be $1\frac{1}{2}$ in. [38 mm] for Grade A, and $3\frac{3}{4}$ in. [95 mm] for Grades E and F (4 in. [102 mm] maximum as heat treated).

NOTE—These grades are similar to corresponding grades in Specification A 517/A 517M.

1.2 Welding technique is of fundamental importance and it is presupposed that welding procedures will be in accordance with approved methods for the class of material used.

1.3 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as the standard; within the text and tables, the SI units are shown in [brackets]. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 517/A 517M Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered

A 788 Specification for Steel Forgings, General Requirements

E 112 Methods for Determining the Average Grain Size

3. Ordering Information and General Requirements

3.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order a detailed drawing, a sketch, or written description of the forging.

3.2 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Melting Process* — The steel shall be made in accordance with the Melting Process Section of Specification A 788.

4.2 *Grain Size* — The steel shall be fully killed, fine grained (ASTM No. 5 or finer), as determined in accordance with Test Methods E 112, Plate IV. 98

4.3 *Discard* — Sufficient discard shall be made from each ingot to ensure freedom from piping and excessive segregation.

4.4 The finished product shall be a hot-worked forging as defined by Specification A 788, and shall be forged as closely as practicable to the finished shape and size.

5. Heat Treatment

5.1 After forging and before reheating, the forgings shall be cooled to provide substantially complete transformation of austenite. Heat treatment for properties shall consist of heating the forgings to not less than 1650°F [900°C], quenching in a liquid medium, and tempering at 1150°F [620°C] minimum, with a holding time of 1 h/in. [1 h/25 mm] minimum, but in no case less than ½ h. Forgings with sections over 2½ to 4 in. [65 to 100 mm] inclusive, shall be liquid quenched from a temperature not less than 1750°F [955°C] prior to the above treatment for properties.

6. Chemical Requirements

6.1 *Heat Analysis* — The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1.

6.2 *Product Analysis* — The purchaser may use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat.

7. Mechanical Requirements

7.1 The forgings as represented by tension tests shall conform to the requirements prescribed in Table 2. Charpy V-notch impact specimens shall have a lateral expansion opposite the notch of not less than 0.015 in. (15 mils) [0.38 mm]. In addition, the values of energy absorption in foot-pounds (or joules) and the fracture appearance in percent shear shall be recorded and reported for information.

7.2 *Sampling:*

7.2.1 Samples for mechanical test specimens shall be removed after the quenching and tempering heat treatment. The purchaser shall specify any additional thermal treatments that shall be given to the test specimens in addition to the heat treatment specified in 5.1. (This is intended to simulate thermal treatments which may subsequently be performed by the fabricator.)

7.2.2 Samples shall be removed so that the test specimens will have their major axes parallel to the direction of major working of the forging.

7.2.3 Test specimens may be machined from a production forging, or prolongation thereof, or from special forged blocks suitably worked and heat treated with the production forgings. Such special blocks shall be obtained from the ingot, slab, or billet and be reduced by forging in a manner similar to that for the products to be represented. The maximum reduction for a special test block shall not exceed the minimum reduction of the forgings represented, and its thickness shall not be less than the maximum thickness of the forgings represented. If a forging is tested, the tests must represent the maximum section thickness in the lot. All test specimens shall be located at the midplane of the thickness and at least *T* from any second surface of the production forging or test block. (*T* equals the maximum thickness of the forging.)

7.3 *Number of Tests and Retests:*

7.3.1 *Number of Tests:*

7.3.1.1 One room-temperature tension test and one set of three Charpy V-notch specimens shall be made to represent the maximum section from each heat in each heat-treatment charge. Impact tests shall be conducted at the temperature specified on the order, but no higher than 32°F [0°C].

7.3.1.2 One grain size test shall be made from each heat.

7.3.2 *Retests of Tension Specimens* — If the results of tension tests do not conform to the requirements specified, retests are permitted, as outlined in 7.3.2.1, 7.3.2.2, and 7.3.2.3.

7.3.2.1 If the percentage of elongation of a tension test specimen is less than that prescribed in Table 2, and any part of the fracture is outside the middle half of the gage length, indicated by scribe marks on the test specimens, a single retest shall be allowed.

7.3.2.2 If a test specimen fails to meet the minimum specified requirements due to a flaw, other than a rupture, crack, or flake, a single retest shall be allowed.

7.3.2.3 In the case of failure of the mechanical test specimens to conform to the minimum specified requirements, the manufacturer may reheat treat the forgings. Testing after reheat treatment shall consist of

the full number of specimens taken from locations complying with the specification or order.

7.3.3 *Retests of Impact Specimens:*

7.3.3.1 If the lateral expansion value for one specimen is below 0.015 in. [0.38 mm] but not below 0.010 in. [0.25 mm] and the average equals or exceeds 0.015 in. [0.38 mm], a retest of three additional specimens may be made. Each of the three retest specimens must equal or exceed the specified minimum value of 0.015 in. [0.38 mm].

7.3.3.2 If the required lateral expansion values are not obtained in the retest, or if the values in the initial test are below the required values for retest, no further retests are permitted unless the forgings are reheat treated. After reheat treatment, a set of three specimens shall be tested and each must equal or exceed the specified minimum value of 0.015 in. [0.38 mm].

98 **7.4** *Test Methods* — Tension and impact tests shall be made in accordance with the latest issue of Test Methods and Definitions A 370. Tension specimens shall be the standard 0.500-in. [12.5-mm] round by 2-in. [50-mm] gage length (see Fig. 5 (Suggested Types of Ends for Standard Round Tension Test Specimens), Test Methods and Definitions A 370). In case of sections too small to accommodate this standard specimen, the largest practicable small size specimen shown in Fig. 4 shall be used. The impact specimens shall be the Charpy V-notch, as shown in Fig. 10 (Charpy (Simple-Beam) Impact Test) of Test Methods and Definitions A 370.

8. Repair Welding

8.1 Repair welding of forgings may be permitted but only at the option of the purchaser. Such repair welds shall be made in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

9. Product Marking

9.1 Each forging shall be identified in accordance with the Marking Section of Specification A 788.

10. Test Reports

10.1 The certification requirements of Specification A 788 shall apply.

11. Keywords

11.1 high-strength low-alloy steel; pipe fittings— 98
steel; pressure vessel service; quenched and tempered steel; steel forgings—alloy

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A[A]	Grade E[A]	Grade F[A]
Carbon			
Heat	0.15–0.21	0.12–0.20	0.10–0.20
Product	0.13–0.23	0.10–0.22	0.08–0.22
Manganese			
Heat	0.80–1.10	0.40–0.70	0.60–1.00
Product	0.75–1.15	0.37–0.74	0.55–1.05
Phosphorus, max	.025	.025	.025
Sulfur, max	.025	.025	.025
Silicon			
Heat	0.40–0.80	0.20–0.35	0.15–0.35
Product	0.35–0.86	0.18–0.37	0.13–0.37
Nickel			
Heat	. . .	. . .	0.70–1.00
Product	. . .	. . .	0.67–1.03
Chromium			
Heat	0.50–0.80	1.40–2.00	0.40–0.65
Product	0.46–0.84	1.34–2.06	0.36–0.79
Molybdenum			
Heat	0.18–0.28	0.40–0.60	0.40–0.60
Product	0.15–0.31	0.36–0.64	0.36–0.64
Vanadium			
Heat	. . .	[B]	0.03–0.08
Product	. . .	. . .	0.02–0.09
Titanium			
Heat	. . .	0.04–0.10	. . .
Product	. . .	0.03–0.11	. . .
Zirconium			
Heat	0.05–0.15	. . .	. . .
Product	0.04–0.16	. . .	. . .
Copper			
Heat	. . .	0.20–0.40	0.15–0.50
Product	. . .	0.17–0.43	0.12–0.53
Boron	0.0025 max	0.0015–0.005	0.002–0.006

[A] Similar to Specification A 517/A 517M Grades A, E, and F, respectively.
[B] May be substituted for part or all of titanium content on a one for one basis.

TABLE 2
TENSILE REQUIREMENTS

	Up to 2½ in. [65 mm], incl	Over 2½ in. to 4 in. [65 to 100 mm], incl
Tensile strength, psi (MPa)	115 000 to 135 000 [795 to 930]	105 000 to 135 000 [725 to 930]
Yield strength (0.2% offset), min, psi [MPa]	100 000 [690]	90 000 [620]
Elongation in 2 in. [50 mm], min, %	18	17
Reduction of area, min, %	45	40

SPECIFICATION FOR CASTINGS, CARBON, LOW-ALLOY, AND MARTENSITIC STAINLESS STEEL, ULTRASONIC EXAMINATION THEREOF

SA-609/SA-609M

(Identical with ASTM Specification A 609/A 609M-91)

1. Scope

1.1 This practice covers the standards and procedures for the pulse-echo ultrasonic examination of heat-treated carbon, low-alloy, and martensitic stainless steel castings by the longitudinal-beam technique.

1.2 This practice is to be used whenever the inquiry, contract, order, or specification states that castings are to be subjected to ultrasonic examination in accordance with Practice A 609/A 609M.

1.3 This practice contains two procedures for ultrasonic inspection of carbon, low-alloy, and martensitic stainless steel castings, that is, Procedure A and Procedure B. Procedure A is the original A 609/A 609M practice and requires calibration using a series of test blocks containing flat bottomed holes. It also provides supplementary requirements for angle beam testing. Procedure B requires calibration using a back wall reflection from a series of solid calibration blocks.

NOTE 1 — Ultrasonic examination and radiography are not directly comparable. This examination technique is intended to complement Guide E 94 in the detection of discontinuities.

1.4 The values stated in either inch–pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this practice.

1.5 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

E 94 Guide for Radiographic Testing

E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments

2.2 *Other Document:*

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Ordering Information

3.1 The inquiry and order should specify which procedure is to be used. If a procedure is not specified, Procedure A shall be used.

3.2 *Procedure A — Flat-Bottomed Hole Calibration Procedure:*

3.2.1 When this practice is to be applied to an inquiry, contract, or order, the purchaser shall furnish the following information:

3.2.1.1 Quality levels for the entire casting or portions thereof,

3.2.1.2 Sections of castings requiring longitudinal-beam examination,

3.2.1.3 Sections of castings requiring dual element examination,

3.2.1.4 Sections of castings requiring supplementary examination, using the angle-beam procedure described in Supplementary Requirement S1 in order to achieve more complete examination, and

3.2.1.5 Any requirements additional to the provisions of this practice.

3.3 *Procedure B: Back-Wall Reflection Calibration Procedure* — When this procedure is to be applied to an inquiry, contract, or order, the purchaser shall designate the quality levels for the entire casting or applicable portions.

PROCEDURE A — FLAT-BOTTOMED HOLE CALIBRATION PROCEDURE

4. Apparatus

4.1 *Electronic Apparatus:*

4.1.1 An ultrasonic, pulsed, reflection type of instrument that is capable of generating, receiving, and amplifying frequencies of at least 1 to 5 MHz.

4.1.2 The ultrasonic instrument shall provide linear presentation (within ±5%) for at least 75% of the screen height (sweep line to top of screen). Linearity shall be determined in accordance with Practice E 317 or equivalent electronic means.

4.1.3 The electronic apparatus shall contain a signal attenuator or calibrated gain control that shall be accurate over its useful range to ±10% of the nominal attenuation or gain ratio to allow measurement of signals beyond the linear range of the instrument.

4.2 *Search Units:*

4.2.1 *Longitudinal Wave*, internally grounded, having a ½ to 1⅛ in. [13 to 28 mm] diameter or 1 in. [25 mm] square piezo-electric elements. Based on the signals-to-noise ratio of the response pattern of the casting, a frequency in the range from 1 to 5 MHz shall be used. The background noise shall not exceed 25% of the distance amplitude correction curve (DAC). Transducers shall be utilized at their rated frequencies.

4.2.2 *Dual-Element*, 5 MHz, ½ by 1 in. [13 by 25 mm], 12° included angle search units are recommended for sections 1 in. [25 mm] and under.

4.2.3 Other frequencies and sizes of search units may be used for evaluating and pinpointing indications.

4.3 *Reference Blocks:*

4.3.1 Reference blocks containing flat-bottom holes shall be used to establish test sensitivity in accordance with 8.2.

4.3.2 Reference blocks shall be made from cast steels that give an acoustic response similar to the castings being examined.

4.3.3 The design of reference blocks shall be in accordance with Fig. 1, and the basic set shall consist of those blocks listed in Table 1. When section thicknesses over 15 in. [380 mm] are to be inspected, an additional block of the maximum test thickness shall be made to supplement the basic set.

4.3.4 Machined blocks with 3/32 in. [2.4 mm] diameter flat-bottom holes at depths from the entry surface of ⅛ in. [3 mm], ½ in. [13 mm], or ½t and ¾ in. [19 mm], or ¾t (where t = thickness of the block) shall be used to establish the DAC for the dual-element search units (see Fig. 2).

4.3.5 Each reference block shall be permanently identified along the side of the block indicating the material and the block identification.

4.4 *Couplant* — A suitable couplant having good wetting characteristics shall be used between the search unit and examination surface. The same couplant shall be used for calibrations and examinations.

5. Personnel Requirements

5.1 The manufacturer shall be responsible for assigning qualified personnel to perform ultrasonic examination in conformance with the requirements of this practice.

5.2 Personnel performing ultrasonic examinations in accordance with this practice shall be familiar with the following:

5.2.1 Ultrasonic terminology,

5.2.2 Instrument calibration,

5.2.3 Effect of transducer material, size, frequency, and mode on test results,

5.2.4 Effect of material structure (grain size, cleanliness, etc.) on test results,

5.2.5 Effect of test distance on test results,

5.2.6 Effect of nonlinearity on test results,

5.2.7 Effect of thickness and orientation of discontinuities on test results, and

5.2.8 Effect of surface roughness on test results.

5.3 A qualification record (see Note 2) of personnel considered suitable by the manufacturer to perform examinations in accordance with this practice shall be available upon request.

NOTE 2 — SNT-TC-1A, Ultrasonic Testing Method, provides a recommended procedure for qualifying personnel. Other personnel qualification requirement documents may be used when agreed upon between the purchaser and the supplier.

6. Casting Conditions

6.1 Castings shall receive at least an austenitizing heat treatment before being ultrasonically examined.

6.2 Test surfaces of castings shall be free of material that will interfere with the ultrasonic examination. They may be as cast, blasted, ground, or machined.

6.3 The ultrasonic examination shall be conducted prior to machining that prevents an effective examination of the casting.

7. Test Conditions

7.1 To assure complete coverage of the specified casting section, each pass of the search unit shall overlap by at least 10% of the width of the transducer.

7.2 The rate of scanning shall not exceed 6 in./s (150 mm/s).

7.3 The ultrasonic beam shall be introduced perpendicular to the examination surface.

8. Procedure

8.1 Adjust the instrument controls to position the first back reflection for the thickness to be tested at least one half of the distance across the cathode ray tube.

8.2 Using the set of reference blocks spanning the thickness of the casting being inspected, mark the flat-bottom hole indication height for each of the applicable blocks on the cathode ray tube shield. Draw a curve through these marks on the screen or on suitable graph paper. The maximum signal amplitude for the test blocks used shall peak at approximately three-fourths of the screen height above the sweep by use of the attenuator. This curve shall be referred to as the 100% distance amplitude correction (DAC) curve. If the attenuation of ultrasound in the casting thickness being examined is such that the system's dynamic range is exceeded, segmented DAC curves are permitted.

8.3 The casting examination surface will normally be rougher than that of the test blocks; consequently, employ a transfer mechanism to provide approximate compensation. In order to accomplish this, first select a region of the casting that has parallel walls and a surface condition representative of the rest of the casting as a transfer point. Next, select the test block whose overall length, *C* (Fig. 1), most closely matches the reflection amplitude through the block length. Place the search unit on the casting at the transfer point and adjust the instrument gain until the back reflection amplitude through the casting matches that through the test block. Using this transfer technique, the examination sensitivity in the casting may be expected to be within ±30% or less of that given by the test blocks.

8.4 Do not change those instrument controls and the test frequency set during calibration, except the attenuator, or calibrated gain control, during acceptance examination of a given thickness of the casting. Make a periodic calibration during the inspection by checking the amplitude of response from the $\frac{1}{4}$-in. (6.4-mm) diameter flat-bottom hole in the test block utilized for the transfer.

NOTE 3 — The attenuator or calibrated gain control may be used to change the signal amplitude during examination to permit small amplitude signals to be more readily detected. Signal evaluation is made by returning the attenuator or calibrated gain control to its original setting.

8.5 During examination of areas of the casting having parallel walls, recheck areas showing 75% or greater loss of back reflection to determine whether loss of back reflection is due to poor contact, insufficient couplant, misoriented discontinuity, etc. If the reason for loss of back reflection is not evident, consider the area questionable and further investigate.

9. Report

9.1 The manufacturer's report of final ultrasonic examination shall contain the following data and shall be furnished to the purchaser:

9.1.1 The total number, location, amplitude, and area when possible to delineate boundaries by monitoring the movement of the center of the search unit of all indications equal to or greater than 100% of the DAC,

9.1.2 Questionable areas from 8.5 that, upon further investigation, are determined to be caused by discontinuities,

9.1.3 The examination frequency, type of instrument, types of search units employed, couplant, manufacturer's identifying numbers, purchaser's order number, and data and authorized signature, and

9.1.4 A sketch showing the physical outline of the casting, including dimensions of all areas not inspected due to geometric configuration, with the location and sizes of all indications in accordance with 9.1.1 and 9.1.2.

10. Acceptance Standards

10.1 This practice is intended for application to castings with a wide variety of sizes, shapes, compositions, melting processes, foundry practices, and applications. Therefore, it is impractical to specify an ultrasonic quality level that would be universally applicable to such a diversity of products. Ultrasonic acceptance or rejection criteria for individual castings should be based on a realistic appraisal of service requirements and the quality that can normally be obtained in production of the particular type of casting.

10.2 Acceptance quality levels shall be established between the purchaser and the manufacturer on the basis of one or more of the following criteria:

10.2.1 No indication equal to or greater than the DAC over an area specified for the applicable quality level of Table 2.

10.2.2 No reduction of back reflection of 75% or greater that has been determined to be caused by a discontinuity over an area specified for the applicable quality level of Table 2.

10.2.3 Indications producing a continuous response equal to or greater than the DAC with a dimension exceeding the maximum length shown for the applicable quality level shall be unacceptable.

10.2.4 Other criteria agreed upon between the purchaser and the manufacturer.

10.3 Other means may be used to establish the validity of a rejection based on ultrasonic inspection.

NOTE 4 — The areas for the ultrasonic quality levels in Table 2 of Practice A 609/A 609M refer to the surface area on the casting over which a continuous indication exceeding the DAC is maintained.

NOTE 5 — Areas are to be measured from dimensions of the movement of the search unit by outlining locations where the amplitude of the indication is 100% of the DAC or where the back reflection is reduced by 75%, using the center of the search unit as a reference point to establish the outline of the indication area.

NOTE 6 — In certain castings, because of very long metal path distances or curvature of the examination surfaces, the surface area over which a given discontinuity is detected may be considerably larger or smaller than the actual area of the discontinuity in the casting; in such cases, other criteria that incorporate a consideration of beam angles or beam spread must be used for realistic evaluation of the discontinuity.

PROCEDURE B — BACK-WALL REFLECTION CALIBRATION PROCEDURE

11. Apparatus

11.1 Apparatus shall be kept on a regular six month maintenance cycle during which, as a minimum requirement, the vertical and horizontal linearities, sensitivity, and resolution shall be established in accordance with the requirements of Practice E 317.

11.2 *Search Units* — Ceramic element transducers not exceeding 1.25 in. [82 mm] diameter or 1 in.^{2} [25 mm^2] shall be used.

11.3 *Search Units Facing* — A soft urethane membrane or neoprene sheet, approximately 0.025 in. [0.64 mm] thick, may be used to improve coupling and minimize transducer wear caused by casting surface roughness.

11.4 *Calibration/Testing* — The same system, including the urethane membrane, used for calibration shall be used to inspect the casting.

11.5 *Other Inspections* — Other frequencies and type search units may be used for obtaining additional information and pinpointing of individual indications.

11.6 *Couplant* — A suitable liquid couplant, such as clean SAE 30 motor oil or similar commercial ultrasonic couplant, shall be used to couple the search unit to the test surface. Other couplants may be used when agreed upon between the purchaser and supplier.

11.7 *Reference Standards* — Reference standards in accordance with Fig. 3 shall be used to calibrate the instrument for inspecting machined and cast surfaces. Reference standards shall be flaw free and machined within tolerances indicated.

12. Ultrasonic Instrument

12.1 *Type* — Pulsed ultrasonic reflection instrument capable of generating, receiving, and amplifying frequencies of 1 MHz to 5 MHz shall be used for testing.

12.2 *Voltage* — Line voltage shall be suitably regulated by constant voltage equipment and metal housing must be grounded to prevent electric shock.

12.3 *Linearity* — The instrument must provide a linear presentation (within ±5%) of at least 1.5 in. [40 mm] sweep to peak (S/P).

12.4 *Calibrated Gain Control of Attenuator* — The instrument shall contain a calibrated gain control or signal attenuator (accurate within ±10%) which will allow indications beyond the linear range of the instrument to be measured.

12.5 *Time-Corrected Gain* — The instrument shall be equipped to compensate for signal decay with distance. A method should be available to equalize signal response at different depths.

13. Qualification

13.1 The requirements for pre-production qualification are as follows:

13.1.1 *Personnel* — The personnel qualification requirements of SNT-TC-1A are applicable. Other personnel qualification requirement documents may be used when agreed upon between the purchaser and the supplier. Records of all personnel shall be available to customers upon request.

13.1.2 *Equipment* — The equipment shall be capable of meeting the requirements in Section 12.

14. Preparation

14.1 *Time of Inspection* — The final ultrasonic acceptance inspection shall be performed after at least an austenitizing heat treatment and preferably after machining. In order to avoid time loss in production, acceptance inspection of cast surfaces may be done prior to machining. Machined surfaces shall be acceptance inspected as soon as possible after machining. Repair welds may be inspected before the postweld heat treatment.

14.2 *Surface Finish:*

14.2.1 *Machined Surfaces* — Machined surfaces subject to ultrasonic inspection shall have a finish that will produce an ultrasonic response equivalent to that obtained from a 250 μin. (6.3 μm) surface. The surface finish shall also permit adequate movement of search units along the surface.

14.2.2 *Casting Surfaces* — Casting surfaces to be ultrasonically inspected shall be suitable for the intended type and quality level (Tables 3 and 4) of inspection as judged acceptable by a qualified individual as specified in 13.1.1.

14.2.3 *Surface Condition* — All surfaces to be inspected shall be free of scale, machining or grinding particles, excessive paint thickness, dirt, or other foreign matter that may interfere with the inspection.

14.3 *Position of Casting* — The casting shall be positioned such that the inspector has free access to the back wall for the purpose of verifying change in contour.

15. Calibration

15.1 *Calibration Blocks* — Determine the thickness of the material to be ultrasonically inspected. For material thickness of 3 in. [75 mm] or less, use the series of 3 blocks, ½, 2, 5 in. [13, 50, 125 mm] (Fig. 3, B dimension) for calibration. For a material thickness greater than 3 in., use the series of 3 blocks, 2, 5, 10 in. [50, 125, 250 mm] (Fig. 3, B dimension) for calibration.

15.2 *Calibration of Search Units* — For the thickness of material to be inspected, as determined in 15.1, use the following search units:

15.2.1 For materials 3 in. [75 mm] or less in thickness, use a 2¼ MHz, ½ in. [13 mm] diameter search unit.

15.2.2 For material greater than 3 in. [75 mm] in thickness, use a 2¼ MHz, 1 in. [25 mm] diameter search unit.

15.3 *Calibration Procedure:*

15.3.1 Set the frequency selector as required. Set the reject control in the "OFF" position.

15.3.2 Position the search unit on the entrant surface of the block that completely encompasses the metal thickness to be inspected (Fig. 3) and adjust the sweep control such that the back reflection signal appears approximately, but not more than three-quarters along the sweep line from the initial pulse signal.

15.3.3 Position the search unit on the entrant surface of the smallest block of the series of 3 blocks selected for calibration and adjust the gain until the back reflection signal height (amplitude) is 1.5 in. [40 mm] sweep to peak (S/P). Draw a line on the cathode-

ray screen (CRT), parallel to the sweep line, through the peak of the 1.5 in. (S/P) amplitude.

15.3.4 Position the search unit on the entrant surface of the largest block of the series of 3 blocks selected for calibration, and adjust the distance amplitude control to provide a back reflection signal height of 1.5 in. [40 mm] (S/P).

15.3.5 Position the search unit on the entrant surface of the intermediate calibration block of the series of 3 blocks being used for calibration and confirm that the back reflection signal height is approximately 1.5 in. [40 mm] (S/P). If it is not, obtain the best compromise between this block and the largest block of the series of 3 blocks being used for calibration.

15.3.6 Draw a line on the cathode ray tube screen parallel to the sweep line at 0.5 in. [13 mm] (S/P) amplitude. This will be the reference line for reporting discontinuity amplitudes.

15.3.7 For tests on *machined surfaces*, position the search unit on a machined surface of casting where the walls are reasonably parallel and adjust the gain of the instrument until the back reflection signal height is 1.5 in. [40 mm] (S/P). Increase the inspection sensitivity by a factor of three times (10 dB gain) with the calibrated attenuator. Surfaces that do not meet the requirements of 14.2.1 shall be inspected as specified in 15.3.8.

15.3.8 For inspections on *cast surfaces*, position the search unit on the casting to be inspected at a location where the walls are reasonably parallel and smooth (inside and outside diameter) and the surface condition is representative of the surface being inspected. Adjust the gain of the instrument until the back reflection signal height is 1.5 in. [40 mm] (S/P). Increase the inspection sensitivity by a factor of six times (16 dB) by use of the calibrated control or attenuator. A significant change in surface finish requires a compensating adjustment to the gain.

15.3.8.1 Rejectable indications on as-cast surfaces may be reevaluated by surface preparation to 250 μin. [6.3 μm] finish or better, and re-inspected in accordance with 15.3.7 of this practice.

15.3.8.2 It should be noted that some instruments are equipped with decibel calibrated gain controls, in which case the decibel required to increase the sensitivity must be added. Other instruments have decibel calibrated attenuators, in which case the required decibel must be removed. Still other instruments do not have calibrated gains or attenuators. They require external attenuators.

16. Scanning

16.1 *Grid Pattern* — The surface of the casting shall be laid out in a 12 by 12 in. [300 by 300 mm] or any similar grid pattern for guidance in scanning. Grid numbers shall be stenciled on the casting for record purposes and for grid area identity. The stenciled grid number shall appear in the upper right hand corner of the grid. When grids are laid out on the casting surface and they encompass different quality levels, each specific area shall be evaluated in accordance with the requirements of the specific quality level designated for that area.

16.2 *Overlap* — Scan over the surface allowing 10% minimum overlap of the working diameters of the search unit.

16.3 *Inspection Requirements* — All surfaces specified for ultrasonic (UT) shall be completely inspected from both sides, whenever both sides are accessible. The same search unit used for calibration shall be used to inspect the casting.

17. Additional Transducer Evaluation

17.1 Additional information regarding any ultrasonic indication may be obtained through the use of other frequency, type, and size search unit.

18. Acceptance Criteria

18.1 *Rejectable Conditions* — The locations of all indications having amplitudes greater than the 0.5 in. [13 mm] line given in 15.3.6, when amplitude three times (machined surfaces) or six times (cast surfaces) shall be marked on the casting surface. The boundary limits of the indication shall be determined by marking a sufficient number of marks on the casting surfaces where the ultrasonic signal equals one half the reference amplitude, 0.25 in. [6 mm]. To completely delineate the indication, draw a line around the outer boundary of the center of the number of marks to form the indication area. Draw a rectangle or other regular shape through the indication in order to form a polygon from which the area may be easily computed. It is not necessary that the ultrasonic signal exceed the amplitude reference line over the entire area. At some locations within the limits of the indication, the signal may be

less than the reference line, but nevertheless still present such that it may be judged as a continuous, signal indication. Rejectable conditions are as follows and when any of the conditions listed below are found, the indications shall be removed and repair welded to the applicable process specification.

18.2 *Linear Indications* — A linear indication is defined as one having a length equal to or greater than three times its width. An amplitude of ½ in. [13 mm], such as would result from tears or stringer type slag inclusion, shall be removed.

18.3 *Non-Linear Indications:*

18.3.1 *Isolated Indications* — Isolated indications shall not exceed the limits of the quality level designated by the customer's purchase order listed in Table 3. An isolated indication may be defined as one for which the distance between it and an adjacent indication is greater than the longest dimension of the larger of the adjacent indications.

18.3.2 *Clustered Indications* — Clustered indications shall be defined as two or more indications that are confined in a 1 in. [25 mm] cube. Clustered indications shall not exceed the limits of the quality level designated by the customer purchase order in Table 4. Where the distance between indications is less than the lowest dimension of the largest indication in the group, the cluster shall be repair welded.

18.3.3 The distance between two clusters must be greater than the lowest dimension of the largest indication in either cluster. If they are not, the cluster having the largest single indication shall be removed.

18.3.4 All indications, regardless of their surface areas as indicated by transducer movement on the casting surface and regardless of the quality level required, shall not have a through wall distance greater than $\frac{1}{3}T$, where T is the wall thickness in the area containing the indication.

18.3.5 Repair welding of cluster-type indications need only be the extent necessary to meet the applicable quality level for that particular area. All other types of rejectable indications shall be completely removed.

18.3.6 Repair welds of castings shall meet the quality level designated for that particular area of the casting.

18.3.7 Any location that has a 75% or greater loss in back reflection and exceeds the area of the applicable quality level, and whose indication amplitudes may or may not exceed the 0.5 in. [13 mm] rejection line, shall be rejected unless the reason for the loss in back reflection can be resolved as not being caused by an indication. If gain is added and back echo is achieved without indication percent amplitude exceeding the 0.5 in. [13 mm] rejection line, the area should be accepted.

19. Records

19.1 *Stenciling* — Each casting shall be permanently stenciled to locate inspection zones or grid pattern for ease in locating areas where rejectable indications were observed.

19.2 *Sketch* — A report showing the exact depth and surface location in relation to the stencil numbers shall be made for each rejectable indicator found during each inspection.

19.2.1 The sketch shall also include, but not be limited to, the following:

19.2.1.1 Part identification numbers,

19.2.1.2 Purchase order numbers,

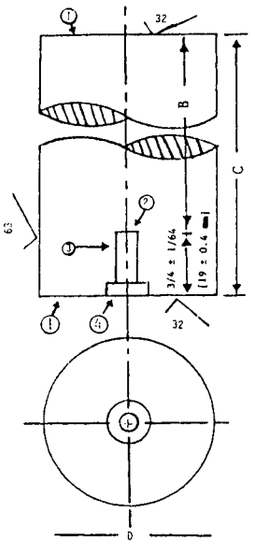
19.2.1.3 Type and size of supplemental transducers used,

19.2.1.4 Name of inspector, and

19.2.1.5 Date of inspection.

20. Product Marking

20.1 Any rejectable areas (those indications exceeding the limits of Section 19) shall be marked on the casting as the inspection progresses. The point of marking shall be the center of the search unit.



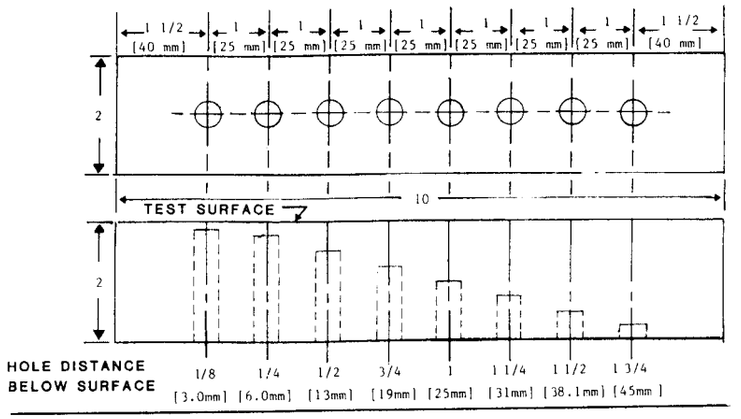
NOTE 1—Opposite ends of reference block shall be flat and parallel within 0.001 in. [0.025 mm].

NOTE 2—Bottom of flat-bottom hole shall be flat within 0.002-in. [0.051 mm] and the finished diameter shall be ¼ + 0.002 in. [6.4 + 0.050 mm].

NOTE 3—Hole shall be straight and perpendicular to entry surface within 0°, 30 min and located within 1/32 in. [0.80 mm] of longitudinal axis.

NOTE 4—Counter bore shall be ½ in. [15.0 mm] diameter by ⅛ in. [5 mm] deep.

FIG. 1 ULTRASONIC STANDARD REFERENCE BLOCK



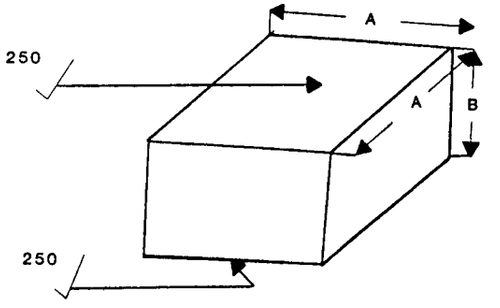
NOTE 1—Entrant surface shall be 250 µin. [6.3 µm] or finer.

NOTE 2— The 3/32-in. [2.4 mm] flat-bottom hole must be flat within 0.002 in. [0.05 mm]. Diameter must be within +0.005 in. [0.13 mm] of the required diameter. Hole axis must be perpendicular to the block and within an angle of 0°, 30 min.

NOTE 3—Hole shall be plugged following checking for ultrasonic response.

in.	[mm]	in.	[mm]
1/8	[3]	1 1/4	[32]
1/4	[6]	1 1/2	[38]
1/2	[13]	1 3/4	[44]
3/4	[19.0]	2	[50]
1	[25]	10	[254]

FIG. 2 ULTRASONIC STANDARD REFERENCE BLOCK FOR DUAL-SEARCH UNIT CALIBRATION

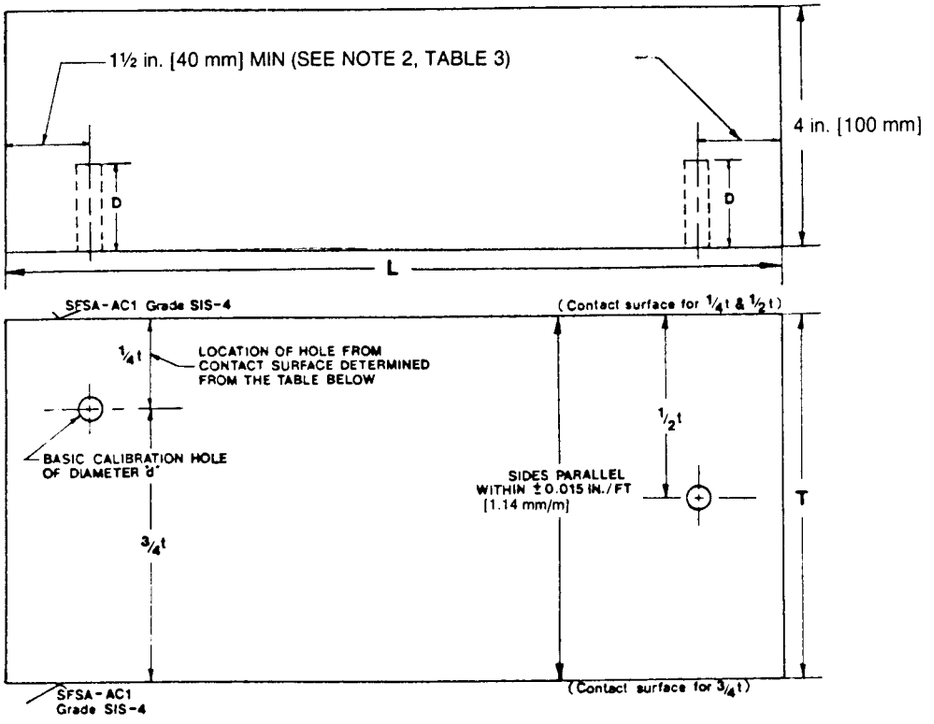


Dimensions, in. [mm]		Material
2 [50]	1/2 [13]	Specification A 217/A 217M, Grade WC6 or acoustically similar within ±20 % or 2 dB.
2 [50]	2 [50]	
3 [75]	5 [125]	
6 [150]	10 [250]	

Tolerance

All sides to be flat within 0.0002 in. [0.01 mm] and parallel with 0.001 in. [0.03 mm].

FIG. 3 CALIBRATION BLOCKS



L = length of block determined by the angle of search unit and the vee-path used,
T = thickness of basic calibration block (see Table 5),
D = depth of side-drilled hole (see Table 5),
d = diameter of side-drilled hole (see Table 5),
t = nominal production material thickness.

FIG. 4 BASIC CALIBRATION BLOCK FOR ANGLE BEAM EXAMINATION

TABLE 1
DIMENSIONS AND IDENTIFICATION OF REFERENCE BLOCKS IN THE BASIC SET
(SEE FIG. 1)

Hole Diameter in 1/64ths, in. [mm]	Metal Distance (*B*), in.[A] [mm]	Overall Length (*C*), in.[A] [mm]	Width or Diameter (*D*), min, in. [mm]	Block Identification Number
16 [0.70]	1 [25]	1 3/4 [45]	2 [50]	16-0100
16 [0.70]	2 [50]	2 3/4 [70]	2 [50]	16-0200
16 [0.70]	3 [75]	3 3/4 [95]	2 [50]	16-0300
16 [0.70]	6 [150]	6 3/4 [170]	3 [75]	16-0600
16 [0.70]	10 [255]	10 3/4 [275]	4 [100]	16-1000
16 [0.70]	B	B + 3/4 [B + 20]	5 [125]	16-B00[B]

[A] Tolerance ± 1/8 in. [3 mm].
[B] Additional supplemental blocks for testing thickness greater than 10 in. [250 mm], see 4.3.3.

TABLE 2
REJECTION LEVEL

NOTE 1 — The areas in the table refer to the surface area on the casting over which a continuous indication exceeding the amplitude reference line or a continuous loss of back reflection of 75% or greater is maintained.

NOTE 2 — Areas shall be measured from the center of the search unit.

NOTE 3 — In certain castings, because of very long test distances or curvature of the test surface, the casting surface area over which a given discontinuity is detected may be considerably larger or smaller than the actual area of the discontinuity in the casting; in such cases a graphic plot that incorporates a consideration of beam spread should be used for realistic evaluation of the discontinuity.

Ultrasonic Testing Quality Level	Area, $in.^2$ [cm^2] (see 10.2.1 and 10.2.2)	Length, max, in. [mm]
1	0.8 [5]	1.5 [40]
2	1.5 [20]	2.2 [55]
3	3 [20]	3.0 [75]
4	5 [30]	3.9 [100]
5	8 [50]	4.8 [120]
6	12 [80]	6.0 [150]
7	16 [100]	6.9 [175]

TABLE 3
ACCEPTANCE CRITERIA FOR SINGLE ISOLATED INDICATIONS

NOTES:
(*1*) The area measured by movement of the center of the transducer over the casting surface.
(*2*) O = outer wall 1/3, or inner wall 1/3.
C = mid wall 1/3.
E = entire wall.

Quality Level	Maximum Non-Linear Indication, Area, in.^{2} [cm^2]	Position of Indication
1	0	E
2	1 [6]	E
3	1 [6]	O
	2 [13]	C
4	3 [19]	E
5	3 [19]	O
	5 [32]	C
6	5 [32]	E
7	5 [32]	O
	7 [45]	C
8	7 [45]	E
9	7 [45]	O
	9 [58]	C
10	9 [58]	E
11	9 [58]	O
	11 [71]	C

TABLE 4
ACCEPTANCE CRITERIA FOR CLUSTERED INDICATIONS

Quality Level	Cumulative Area of Indications, in.^{2} [cm^2][A,B]	Minimum Area in Which Indications Must be Dispersed, in.^{2} [cm^2][C]
1	0	0
2–3	2 [13]	36 [232]
4–5	4 [26]	36 [232]
6–7	6 [39]	36 [232]
8–9	8 [52]	36 [232]
10–11	10 [64]	36 [232]

[A] Regardless of wall location, that is midwall 1/3, innermost 1/3, or outermost 1/3.

[B] Each indication that equals or exceeds the 0.5 in. [18 mm] reference line shall be traced to the position where the indication is equal to 0.25 in. [6 mm]. The area of the location, for the purpose of this evaluation, shall be considered the area that is confined within the outline established by the center of the transducer during tracing of the flaw as required. Whenever no discernible surface tracing is possible, each indication which equals or exceeds the 0.5 in. reference amplitude shall be considered 0.15 in.^{2} [1 cm^2] (three times the area of the 1/4 diameter [6 mm] flat bottomed hole to compensate for reflectivity degradation of natural flaw) for the cumulative area estimates.

[C] The indications within a cluster with the cumulative areas traced shall be dispersed in a minimum surface area of the casting equal to 36 in.^{2} [230 cm^2]. If the cumulative areas traced are confined with a smaller area of distribution, the area shall be repair welded to the extent necessary to meet the applicable quality level.

TABLE 5
DIMENSIONS OF CALIBRATION BLOCKS FOR ANGLE-BEAM EXAMINATION

NOTE 1 — For each increase in thickness of 2 in. [50 mm], or a fraction thereof, the hole diameter shall increase $\frac{1}{16}$ in. [1.6 mm].

NOTE 2 — For block sizes over 3 in. [75 mm] in thickness, *T,* the distance from the hole to the end of the block shall be $\frac{1}{2}$ *T,* min, to prevent coincident reflections from the hole and the corner. Block fabricated with a 2 in. [50 mm] minimum dimension need not be modified if the corner and hole indications can be easily resolved.

Nominal Production Material Thickness (*t*), in. [mm]	Basic Calibration Block Thickness (*T*), in. [mm]	Hole Diameter (*d*), in 1.002 [mm ± 0.05]	Minimum Depth (*D*), in. [mm]
Up to 1 [25] incl	1 [25] or *t*	$\frac{3}{32}$ [2.4]	$1\frac{1}{2}$ [40]
Over 1 to 2 [25–50]	2 [50] or *t*	$\frac{1}{8}$ [3.2]	$1\frac{1}{2}$ [40]
Over 2 to 4 [50–100]	4 [100] or *t*	$\frac{3}{16}$ [4.8]	$1\frac{1}{2}$ [40]
Over 4 to 6 [100–150]	6 [150] or *t*	$\frac{1}{4}$ [6.3]	$1\frac{1}{2}$ [40]
Over 6 to 8 [150–200]	8 [200] or *t*	$\frac{5}{16}$ [7.9]	$1\frac{1}{2}$ [40]
Over 8 to 10 [200–250]	10 [250] or *t*	$\frac{3}{8}$ [9.5]	$1\frac{1}{2}$ [40]
Over 10 [250]	*t*	See Note 1	$1\frac{1}{2}$ [40]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall be applied only when agreed upon between the purchaser and the supplier to achieve an effective examination of a critical casting area that cannot be effectively examined using a longitudinal beam as a result of casting design or possible discontinuity orientation.

S1. Angle Beam Examination of Steel Castings

S1.1 *Equipment:*

S1.1.1 *Examination Instrument* — Examination shall be conducted with an ultrasonic, pulsed-reflection type of system generating frequencies of at least 0.4 to 5 MHz. Properties of the electronic apparatus shall be the same as those specified in 4.1.

S1.1.2 *Search Units* — Angle-beam search units shall produce an angle beam in steel in the range from 30 to 75° inclusive, measured to the perpendicular of the entry surface of the casting being examined. It is preferred that search units shall have frequency of 0.4 to 5 MHz.

S1.1.3 *Calibration Blocks* — A set of blocks, as shown in Fig. 4, with as cast surface equivalent to SCRATA Comparator A3 and of a thickness comparable to the sections being examined with side-drilled holes at $\frac{1}{4}t$, $\frac{1}{2}t$, and $\frac{3}{4}t$ (where t = thickness of the block) shall be used to establish an amplitude reference line (ARL).

S1.2 *Calibration of Equipment:*

S1.2.1 Construct the distance amplitude correction curve by utilizing the responses from the side-drilled holes in the basic calibration block for angle beam examination as shown in Fig. 4 and Table 5.

S1.2.1.1 Resolve and mark the amplitudes of the $\frac{1}{4}t$ and $\frac{1}{2}t$ side-drilled holes from the same surface. The side-drilled hole used for the $\frac{1}{4}t$ amplitude may be used to establish the $\frac{3}{4}t$ amplitude from the opposite surface or a separate hole may be used.

S1.2.1.2 Connect the $\frac{1}{4}t$, $\frac{1}{2}t$, and $\frac{3}{4}t$ amplitudes to establish the applicable DAC.

S1.2.2 The basic calibration blocks shall be made of material that is acoustically similar to the casting being examined.

S1.2.3 Do not use basic calibration blocks with as cast surface equivalent to SCRATA Comparator A3 to examine castings with surface rougher than SCRATA Comparator A3. Use a machined calibration block for machined surfaces.

S1.2.4 The search unit and all instrument control settings remain unchanged except the attenuator or calibrated gain control.

S1.2.4.1 The attenuator or calibrated gain control may be used to change the signal amplitude during examination to permit small amplitude signals to be more readily detected. Signal evaluation is made by returning the attenuator or calibrated gain control to its original setting.

S1.3 *Data Reporting* — The supplier's report of final ultrasonic examination shall contain the following data:

S1.3.1 The total number, location, amplitude, and area of all indications equal to or greater than 100% of the distance amplitude curve.

S1.3.2 The examination frequency, type of instrument, type, and size of search units employed, couplant, transfer method, examination operator, supplier's identifying numbers, purchase order number, date, and authorized signature.

S1.3.3 A sketch showing the physical outline of the casting, including dimensions of all areas not examined due to geometric configuration, with the location of all indications in accordance with S1.3.1.

S1.4 *Acceptance Standards* — Acceptance quality levels shall be established between the purchaser and the manufacturer on the basis of one or more of the following criteria:

S1.4.1 No indication equal to or greater than the DAC over an area specified for the applicable quality level of Table 2.

S1.4.2 Other criteria agreed upon between the purchaser and the manufacturer.

SPECIFICATION FOR FORGINGS, CARBON STEEL, FOR PIPING COMPONENTS WITH INHERENT NOTCH TOUGHNESS

SA-727/SA-727M

(Identical with ASTM Specification A 727/A 727M-96.) 98

1. Scope

1.1 This specification covers forged carbon steel piping components intended primarily for service in pressure piping systems from −20 to +650°F [−30 to +345°C] where inherent notch toughness is desired, but where notch toughness testing is not required. Included are forged or ring-rolled flanges, forged fittings, and valves made to specified dimensions, or to dimensional standards such as the ANSI and API specifications referenced in Section 2.

1.2 This specification is limited to forgings with maximum finished section thicknesses no larger than 2 in. [51 mm].

1.3 It shall be the responsibility of the purchaser to determine whether material meeting the requirements of this specification is satisfactory for the service application.

1.4 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified by the purchaser in the order.

NOTE 1—There are no provisions for impact testing in this specification. When impact testing is required, refer to Specification A 350/A 350M.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents 98

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 350/A 350M Specification for Forgings, Carbon and Low-Alloy Steel, Requiring Notch Toughness Testing for Piping Components

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 751 Test Methods, Practices and Terminology for Chemical Analysis of Steel Products

A 788 Specification for Steel Forgings General Requirements

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition

E 165 Practice for Liquid Penetrant Inspection Method

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

2.2 *MSS Standard:*

SP 25 Standard Marking System for Valves, Fittings, Flanges, and Unions

2.3 *ASME Boiler and Pressure Vessel Codes:*
Section IX, Welding Qualifications
Section II, Material Specifications, Part C
SFA 5.5 Low-Alloy Steel Covered Arc-Welding Electrodes

2.4 *ANSI Standards:*
B 16.5 Steel Pipe Flanges and Flanged Fittings
B 16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves
B 16.11 Forged Steel Fittings, Socket-Welding and Threaded
B 16.30 Unfired Pressure Vessel Flange Dimensions

2.5 *API Standards:*
600 Steel Gate Valves with Flanged or Butt-Welding Ends
602 Compact Design Carbon Steel Gate Valves for Refinery Use
605 Large Diameter Carbon Steel Flanges

98 **3. Ordering Information**

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

3.1.1 Quantity,

3.1.2 Size and pressure class (including which dimensional standard applies) or dimensions (Tolerances and surface finishes should be included),

3.1.3 Specification number (the year should be included),

3.1.4 Supplementary requirements, and

3.1.5 Additional requirements, (see 17.1 and 17.2).

4. Materials and Manufacture

4.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace, and shall be fully killed, fine-grain practice.

4.2 Forgings shall be manufactured from ingots, blooms, billets, slabs, or bars. These items shall be forged, rolled, or strandcast.

4.3 A sufficient discard shall be made from the ingot to secure freedom from injurious piping and undue segregation.

4.4 The finished product shall be a forging as defined by the Terminology section of Specification A 788.

5. Heat Treatment

5.1 Following plastic working, the forging manufacturer shall heat treat the forgings by normalizing, or normalizing and tempering, or quenching and tempering.

5.1.1 *Normalizing*—The procedure for normalizing shall consist of uniformly heating the forgings to a temperature between 1550 and 1700°F [845 and 925°C], holding a sufficient time to attain uniform temperature throughout, and cooling in still air. The forging shall be at a temperature below 1000°F [540°C] before heating for normalizing.

5.1.2 *Quenching*—The procedure for quenching shall consist of uniformly heating the forging to a temperature between 1550 and 1700°F [845 and 925°C], holding a sufficient time to attain uniform temperature throughout, and quenching into a suitable liquid medium. The forging shall be at a temperature below 1000°F [540°C] before heating for quenching.

5.1.3 *Tempering*—The procedure for tempering shall consist of reheating the forging subsequent to normalizing or quenching to a temperature of at least 1100°F [595°C], but not above the lower transformation temperature, for 30 min/in. [30 min/25 mm] of maximum section thickness, with minimum holding time at tempering temperature not less than 30 min.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1. Test Methods, Practices, and Terminology A 751 shall apply.

6.2 Steels to which lead has been added shall not be used.

7. Mechanical Requirements

7.1 *Tension Tests:*

7.1.1 *Requirements*—The material shall conform to requirements for tensile properties prescribed in Table 2.

7.1.1.1 The test specimen shall be obtained from a rough or finished production forging, or prolongation thereof, or it may be obtained from separately forged test blanks from the same heat of steel as the production

forging. The test blank shall be reduced by forging in a manner similar to that for the products represented, shall receive approximately the same hot working and reduction, be of the same nominal thickness, and receive the same heat treatment as the finished products represented. The test material shall be treated in the same furnace at the same time as the forging it represents, subject to the requirements of 7.1.2.1.

7.1.2 *Number of Tests*—One tension test at room temperature shall be made for each nominal wall thickness $\pm 1/4$ in. [±6 mm] from each heat in each heat treatment charge.

7.1.2.1 If heat treatment is performed in either a continuous or a batch-type furnace controlled within ±25°F [±14°C] of the required heat-treatment temperature, and equipped with recording pyrometers so that complete records of heat treatment are available and if the same heat treating cycles are used on the forgings represented by the tension test, then one tension test per nominal wall thickness $\pm 1/4$ in. [±6 mm] from each heat shall be required, instead of one tension test per nominal wall thickness from each heat in each heat-treatment charge.

7.1.3 *Test Locations and Orientations*—The test specimen shall be removed from the midwall of the heaviest section of the forging or test blank.

7.1.3.1 The test specimen shall have its longitudinal axis located parallel to the direction of major working of the forging or test blank, except for flanges and rings the test specimen shall be in the tangential direction.

7.1.4 *Test Method*—Testing shall be performed in accordance with Test Methods and Definitions A 370 using the largest feasible of the round specimens. The gage length for measuring elongation shall be four times the diameter of the test section.

7.2 *Hardness Test:*

7.2.1 *Requirements*—If the production forgings are liquid-quenched and tempered, hardness of the forgings shall not exceed 187 HB after heat treatment. The purchaser may verify that the requirement has been met by testing at any location on the forgings provided such testing does not render the forgings useless.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made from samples taken preferably during the pouring of the heat. The results shall conform to Table 1.

9. Product Analysis

9.1 A product analysis may be made by the purchaser on samples taken in accordance with Practice E 59. The results shall conform to Table 1.

10. Hydrostatic Test

10.1 Forgings manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished forging. Such tests shall be conducted by the forging manufacturer only when Supplementary Requirement S6 is specified.

11. Retests

11.1 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

12. Rework and Retreatment

12.1 If the results of mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings represented, and shall retest to the applicable requirements.

12.2 Individually tested forgings meeting all requirements shall be acceptable.

13. Workmanship, Finish, and Appearance

13.1 The forgings shall be free of injurious defects as defined below and shall have a workmanlike finish. At the discretion of the inspector representing the purchaser, finished forgings shall be subject to rejection if surface imperfections acceptable under 13.3 are not scattered but appear over a large area in excess of what is considered a workmanlike finish.

13.2 *Depth of Injurious Defects*—Selected typical surface imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness of the finished forging, such imperfections shall be considered injurious.

13.3 *Machining or Grinding Imperfections Not Classified as Injurious*—Surface imperfections not classified as injurious shall be treated as follows:

13.3.1 Forgings showing seams, laps, tears, or slivers not deeper than 5% of the nominal wall thickness or $+1/16$ in. [1.6 mm], whichever is less, need not have these imperfections removed. If the imperfections require removal they shall be removed by machining or grinding.

13.3.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed the limitations set forth in 13.2 and if not deeper than $1/16$ in. [1.6 mm]. If such imperfections are deeper than $1/16$ in. [1.6 mm], but do not encroach on the minimum wall thickness of the forging, they shall be removed by grinding to sound metal.

13.3.3 When imperfections have been removed by grinding or machining, the outside dimension at the point of grinding or machining may be reduced by the amount removed. Should it be impracticable to secure a direct measurement, the wall thickness at the point of grinding, or at an imperfection not required to be removed, shall be determined by deducting the amount removed by grinding, from the nominal finished wall thickness of the forging, and the remainder shall be not less than the minimum specified or required wall thickness.

14. Repair by Welding

14.1 Repair of defects by welding shall be permitted at the discretion of the forging manufacturer.

14.2 Repair by welding shall be made using welding procedures and welders qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. When forgings are heat treated after repair welding, the qualification test plates shall be subjected to the same heat treatment. The mechanical properties of the qualification test plates shall conform to Section 7.

14.3 Defects shall be completely removed by chipping or grinding to sound metal as verified by magnetic particle, or liquid penetrant examination prior to welding.

14.4 The weld metal shall be deposited using low-alloy steel electrodes E7015-A1, E7016-A1, or E7018-A1 complying with ASME SFA-5.5.

14.5 After repair welding, the area welded shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic particle or liquid penetrant examination.

14.6 Forgings repair welded in the normalized, normalized and tempered, or the quenched and tempered conditions shall be stress-relieved after repair welding at 1100°F [595°C] minimum, but not higher than the temperature previously used for tempering the base metal of the same forging, or shall be reheat treated in accordance with Section 5.

14.7 Repair by welding shall not exceed 10% of the surface area of the forging, nor $33\frac{1}{3}$% of the wall thickness of the finished forging, or $3/8$ in. [10 mm], whichever is less, without prior approval of the purchaser.

15. Inspection

15.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with the purchase order. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed, except for product analysis (see 9.1).

16. Rejection and Rehearing

16.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

16.2 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed to by the manufacturer and the purchaser.

17. Certification

17.1 For forgings made to specified dimensions, when agreed to by the purchaser, and for forgings made to dimensional standards, application of identification marks as required in Section 18 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification.

17.2 When test reports are required, they shall include certification that all requirements of this specification have been met. The reports shall show the results of all required tests, the heat number or manufacturer's heat identification, a description of the heat treatment

used, and shall be traceable to the forging represented. The specification designation included on test reports shall include year of issue and revision letter, if any.

18. Product Marking

18.1 Identification marks consisting of the specification designation, manufacturer's name or symbol, (Note 3) the heat number or manufacturer's heat identification, size, and service rating, if applicable, shall be permanently placed on each forging in a position that will not affect the usefulness of the forging. When size does not permit complete marking, identification marks may be omitted in the sequence specified in SP 25, except that the word "steel" shall not be substituted for the specification designation. The specification number marked on the forgings need not include specification year of issue and revision letter.

NOTE 3—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

18.1.1 If the forgings have been quenched and tempered the letters "QT" shall be stamped on the forgings following the Specification designation.

18.1.2 Forgings repaired by welding shall be marked with the letter "W" following the specification designation.

18.2 When test reports are required, additional marks shall be used as necessary to identify the part with the test report.

18.3 *Bar Coding* — In addition to the requirements in 18.1 and 18.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag. 98

19. Keywords

19.1 carbon equivalent; pipe fittings, steel; piping applications; pressure containing parts; steel flanges; steel forgings, carbon; steel valves; temperature service applications, low 98

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %
Carbon	
Heat Analysis	0.25 max
Product Analysis	0.28 max
Manganese	
Heat Analysis	0.90 to 1.35
Product Analysis	0.84 to 1.41
Phosphorus	
Heat Analysis	0.035 max
Product Analysis	0.043 max
Sulfur	
Heat Analysis	0.025 max
Product Analysis	0.033 max
Silicon	
Heat Analysis	0.15 to 0.30
Product Analysis	0.13 to 0.32

TABLE 2
TENSILE REQUIREMENTS

Tensile strength, ksi [MPa]	60.0 to 85.0 [415 to 585]
Yield strength, min, ksi [MPa][A]	36.0 [250]
Elongation in 2 in. or 50 mm, min, %	22
Reduction of area, min, %	30

[A] Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification.

S1. Macroetch Test

S1.1 A sample forging shall be sectioned and etched to show flow lines and internal soundness. The tests shall be conducted in accordance with Method E 381.

S1.2 Acceptance limits shall be as agreed upon between the manufacturer and the purchaser.

S2. Product Analysis

S2.1 A product analysis shall be made from one randomly selected forging representing each size and shape of forging on the order. The results shall comply with Table 1.

S2.2 If the analysis fails to comply, each forging shall be checked or the lot rejected. All results shall be reported to the purchaser.

S3. Additional Tension Tests

S3.1 In addition to the requirements of Section 7, the heat identification shall be marked on each forging and one tension specimen shall be obtained from a representative forging or test blank. The procedure for taking the test material shall be agreed upon between the manufacturer and purchaser.

S3.2 The results of the test shall comply with 7.1.1 and shall be reported to the purchaser.

S4. Magnetic Particle Examination

S4.1 Surfaces specified by the purchaser shall be examined by a magnetic particle method in accordance with Test Method A 275/A 275M.

S4.2 Acceptance limits shall be agreed upon between the manufacturer and the purchaser.

S5. Liquid Penetrant Examination

S5.1 Surfaces specified by the purchaser shall be examined by a liquid-penetrant method in accordance with Practice E 165.

S5.2 Acceptance limits shall be agreed upon between the manufacturer and the purchaser.

S6. Hydrostatic Testing

S6.1 A hydrostatic test at a pressure agreed upon between the manufacturer and the purchaser shall be applied by the manufacturer.

S7. Repair Welding

S7.1 No repair welding shall be permitted without prior approval of the purchaser.

S8. Carbon Equivalent

S8.1 The maximum carbon equivalent, based on heat analysis shall be 0.45 for forgings with a maximum section thickness of 2 in. or less, and 0.46 for forgings with a maximum section thickness of greater than 2 in.

S8.2 Determine the carbon equivalent (CE) as follows:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

S8.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

SPECIFICATION FOR SEAMLESS, WELDED FERRITIC, AND MARTENSITIC STAINLESS STEEL PIPE

SA-731/SA-731M

(Identical with ASTM Specification A 731/A 731M-91.) 98

1. Scope

1.1 This specification covers seamless, welded ferritic, and martensitic stainless steel pipe intended for high-temperature and general corrosive service.

1.2 Most of the grades are commonly known as the straight chromium type and are characterized as being ferromagnetic.

1.3 High-chromium, ferritic alloys are highly sensitive to notch brittleness on slow cooling to ordinary temperatures. This feature should be recognized in the use of this material in the as-welded condition in sections thicker than 0.250 in. [6.3 mm].

1.4 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 1 — The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:* 98

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels
E 340 Method for Macroetching Metals and Alloys
E 527 Practice for Numbering Metals and Alloys

2.2 *ANSI Standards:*

B1.20.1 Pipe Threads, General Purpose
B36.10 Welded and Seamless Wrought Steel Pipe
B35.19 Stainless Steel Pipe

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M, unless otherwise provide herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desire material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (ferritic stainless steel pipe),

4.1.3 Process (seamless or welded),

4.1.4 Grade (see Table 1),

4.1.5 Size (NPS or outside diameter and schedule number or average wall thickness),

4.1.6 Length (specific or random, Section 11), and

4.1.7 End finish (see Section on Ends of Specification A 530/A 530M),

4.1.8 Optional requirements (Section 10, and Supplementary Requirements S1 to S6),

4.1.9 Test report required (see Section on Certification of Specification A 530/A 5/30M),

4.1.10 Specification designation, and

4.1.11 Special requirements.

98 5. Materials and Manufacture

5.1 *Manufacture:*

5.1.1 The pipe shall be made by the seamless or by an automatic welding process, with no addition of filler metal in the welding operation.

5.1.2 The pipe shall be pickled free from scale.

5.2 *Heat Treatment* — As a final heat treatment, pipe shall be heated to a temperature of 1400°F [760°C] or higher and cooled (as appropriate for the grade) to meet the requirements of this specification.

5.2.1 The martensitic Grade UNS S41500 shall be heated to a temperature of 950°F (510°C) or higher and cooled as appropriate to meet the requirements of this specification.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Product Analysis

7.1 At the request of the purchaser, an analysis of either one billet, one length of flat-rolled stock, or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

7.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 6.

7.3 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock, or tubes shall be made. Both retests for the elements in question shall meet the requirements of this specification; otherwise all remaining material in the heat or lot shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock, or tubes that do not meet the requirements of this specification shall be rejected.

7.3.1 The lot size for the same NPS of each heat of steel shall be as follows:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5	200 or fraction thereof
6 and over	100 or fraction thereof

8. Tensile Requirements

8.1 The material shall conform to the tensile requirements prescribed in Table 2.

9. Mechanical Requirements

9.1 *Transverse or Longitudinal Tension Test* — The tension test shall be performed on 1% of the pipe from each lot.

NOTE 2 — The term "lot" for mechanical tests applies to all pipe of the same nominal size and wall thickness (or schedule) that is produced from the same heat of steel and subjected to the same finishing treatment: (*1*) in a continuous heat treatment furnace, or (*2*) in a batch-type, heat-treatment furnace, in which case the lot shall include only that pipe heat treated in the same batch furnace charge.

9.2 *Flattening Test* — For material heat treated in a batch-type furnace, flattening tests shall be made on 5% of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall be made on a sufficient number of pipe to constitute 5% of the lot, but in no case less than two lengths of pipe.

9.3 *Hydrostatic Test* — Each length of finished pipe shall be subjected to the hydrostatic test.

10. Lengths

10.1 Pipe lengths shall be in accordance with the following regular practice:

10.1.1 Unless otherwise agreed upon, all sizes are generally available in a length up to 24 ft (Note 3) with the permissible range of 15 to 24 ft (Note 3). Short lengths are acceptable; however, the number and

minimum length shall be agreed upon between the manufacturer and the purchaser.

NOTE 3 — This value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

10.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and not more than $\frac{1}{4}$ in. [6 mm] over that specified.

10.1.3 No jointers are permitted unless otherwise specified.

11. Finish

11.1 The finished pipes shall be straight to within $\frac{3}{16}$ in. [5 mm] maximum bow in any 6 ft [2 m] as measured with a 6 ft [2 m] straight edge. Imperfections may be removed by grinding provided the outside diameter or the wall thickness are not decreased to less than that permitted, in accordance with the Section on Permissible Variations in Wall Thickness or the Table on Permissible Variations in Outside Diameter of Specification A 530/A 530M.

12. Product Marking

12.1 In addition to the marking specified in Specification A 530/A 530M, the marking shall include the manufacturer's private identifying mark and whether the material is seamless or welded.

12.2 The marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the mass.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Grade	18Cr-2Mo	TP XM-33	TP XM-27	TP 439		29-4	29-4-2	26-3-3
	UNS Desig-nation[A]	S44400	S44626	S44527	S43035	S41500[B]	S44700	S44800	S44660
Carbon, max, %		0.025	0.06	0.01[C]	0.07	0.05	0.010	0.010	0.030
Manganese, max, %		1.0	0.75	0.40	1.00	0.05–1.0	0.30	0.30	1.00
Phosphorus, max, %		0.040	0.04	0.02	0.040	0.03	0.025	0.025	0.040
Sulfur, max, %		0.030	0.02	0.02	0.030	0.03	0.020	0.020	0.030
Silicon, max, %		1.00	0.75	0.40	1.00	0.06	0.20	0.20	1.00
Nickel,[D] max, %		1.00	0.50	0.50	0.50	3.5–5.5	0.15 max	2.0–2.5	1.0–3.50
Chromium, %		17.5–19.5	25.0–27.0	25.0–27.5	17.00–19.00	11.5–14.0	28.0–30.0	28.0–30.0	25.0–28.0
Molybdenum, %		1.75–2.50	0.75–1.50	0.75–1.50	. . .	0.5–1.0	3.5–4.2	3.5–4.2	3.0–3.50
Aluminum, max, %		. . .	. . .	. . .	0.15	. . .	. . .	. . .	. . .
Copper, max, %		. . .	0.20	0.20	. . .	. . .	0.15	0.15	. . .
Nitrogen, max, %		0.035	0.040	0.015	0.04	. . .	0.020[E]	0.020[E]	0.040
Titanium, %		Ti + Cb = 0.20 + 4 × (C + N) min; 0.80 max	7 × (C + N) but not less than 0.20 min; 1.00 max	. . .	0.20 + 4 × (C + N) min; 1.10 max	. . .	. . .	. . .	(Ti + Cb) = 0.20–100 and 6 × (C + N) min
Columbium, %		. . .	. . .	0.05–0.20	. . .	. . .	. . .	. . .	. . .

[A] New designation established in accordance with ASTM E 527 and SAE J1066, Practice for Numbering Metals and Alloys (UNS).
[B] Plate version of CA6NM.
[C] For small-diameter piping, where many reduction passes may be required, a carbon maximum of 0.015% is necessary. Small-diameter pipes are defined as those less than 1.315 in. [33.4 mm] in outside diameter.
[D] Nickel plus copper.
[E] Carbon plus nitrogen = 0.025% max.

TABLE 2
TENSILE REQUIREMENTS

Property	Grade					
	18Cr-2Mo	TPXM-33, TPXM-27	TP439	S41500	29-4 29-4-2	28-3-3
Tensile strength, min, psi [MPa]	60 000 [415]	65 000 [450]	60 000 [415]	115 [795]	80 000 [550]	85 [585]
Yield strength, min, psi [MPa]	40 000 [275]	40 000 [275]	30 000 [205]	90 [620]	60 000 [415]	65 [450]
Elongation in 2 in. or 50 mm (or 4*D*) min, %	20	20	20	15	20	20

SUPPLEMENTARY REQUIREMENTS FOR PIPE REQUIRING SPECIAL CONSIDERATION

The supplementary requirements in Sections S1 to S6 shall not be considered unless specified in the order. Those specified in the order shall be made at the mill, unless otherwise agreed upon, and may be witnessed by the purchaser's inspector before shipment of the material.

S1. Product Analysis

S1.1 For all pipe NPS 5 and larger there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10% of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 6 shall be rejected.

S2. Transverse Tests

S2.1 There shall be one transverse tension test made from one end of 10% of the lengths furnished per heat of steel. This applies only to NPS 8 and larger.

S2.2 If a specimen from any length fails to conform to the tensile properties specified, that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test shall be made on specimens from one end of each length of pipe. Crop ends may be used. If the specimen from any length fails to conform to the specified requirement, that length shall be rejected.

S4. Etching Tests

S4.1 An etching test shall be made on a transverse section from one end of each length and shall show sound, homogeneous, and reasonably uniform material, free from injurious laminations, cracks, and similar objectionable defects. An etching test in accordance with Method E 340 shall be made. If the specimen of any length shows objectionable defects, one retest shall be permitted from the same end. If this fails, the length shall be rejected. The rings for the flattening tests (Supplementary Requirement S3) may be used for etch tests either before or after flattening.

S5. Nondestructive Electric Test

S5.1 Each seamless or welded pipe shall be subjected to a nondestructive electric test as agreed upon between the manufacturer and purchaser.

S6. Intergranular Corrosion Test

S6.1 When specified in the purchase order, intergranular corrosion tests shall be run on ferritic stainless steel specimens as described in Practices A 763. The particular corrosion test to be used shall be as specified in Practices A 763.

APPENDIX

(Nonmandatory Information)

X1. TABLE X1.1 IS BASED ON TABLE 1 OF THE AMERICAN NATIONAL STANDARD FOR STAINLESS STEEL PIPE (ANSI B36.19-1965)

TABLE X1.1
DIMENSIONS OF WELDED AND SEAMLESS STAINESS STEEL PIPE

NOTE — The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[A]		Schedule 10S[A]		Schedule 40S[A]		Schedule 80S[A]	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
1/8	0.405	10.29	. . .	. . .	0.049	1.24	0.068	1.73	0.095	2.41
1/4	0.540	13.72	. . .	. . .	0.065	1.65	0.088	2.24	0.119	3.02
3/8	0.675	17.15	. . .	. . .	0.065	1.65	0.091	2.31	0.126	3.20
1/2	0.840	21.34	0.065	1.65	0.083	2.11	0.109	2.77	0.147	3.73
3/4	1.050	26.67	0.065	1.65	0.083	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.41	0.065	1.65	0.109	2.77	0.133	3.38	0.179	4.55
1 1/4	1.660	42.16	0.065	1.65	0.109	2.77	0.140	3.56	0.191	4.85
1 1/2	1.900	48.26	0.065	1.65	0.109	2.77	0.145	3.68	0.200	5.08
2	2.375	60.03	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
2 1/2	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62
3 1/2	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.18	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134	3.40	0.165	4.19	0.365	9.27	0.500[B]	12.70[B]
12	12.750	323.85	0.156	3.96	0.180	4.57	0.375[B]	9.52[B]	0.500[B]	12.70[B]
14	14.000	355.60	0.156[B]	3.96[B]	0.188	4.78	. . .	. . .	. . .	. . .
16	16.000	406.40	0.165[B]	4.19[B]	0.188	4.78	. . .	. . .	. . .	. . .
18	18.000	457.20	0.165[B]	4.19[B]	0.188	4.78	. . .	. . .	. . .	. . .
20	20.000	508.00	0.188[B]	4.78[B]	0.218[B]	5.54[B]	. . .	. . .	. . .	. . .
22	22.000	558.80	0.188[B]	4.78[B]	0.218[B]	5.54[B]	. . .	. . .	. . .	. . .
24	24.000	609.60	0.218[B]	5.54[B]	0.250	6.35	. . .	. . .	. . .	. . .
30	30.000	762.00	0.250	6.35	0.312	7.92	. . .	. . .	. . .	. . .

[A] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).

[B] These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10-1975).

SPECIFICATION FOR PRESSURE VESSEL PLATES, LOW-CARBON AGE-HARDENING NICKEL-COPPER-CHROMIUM-MOLYBDENUM-COLUMBIUM AND NICKEL-COPPER-MANGANESE-MOLYBDENUM-COLUMBIUM ALLOY STEEL

SA-736/SA-736M

[Identical with ASTM Specification A 736/A 736M-88 (Reapproved 1994)]

1. Scope

1.1 This specification covers two grades of low-carbon age-hardening alloy steel plates for welded pressure vessels and piping components. The two grades are nickel-copper-chromium-molybdenum-columbium and nickel-copper-manganese-molybdenum-columbium steels.

1.2 Plates under this specification are available in three Classes, as follows:

1.2.1 *Class 1*—As-rolled and precipitation heat treated. Available in thicknesses of $^{3}/_{4}$ in. [20 mm] and under. Grade A, Class 1 has a minimum specified tensile strength of 90 ksi. Grade C, Class 1 has a minimum specified tensile strength of 100 ksi.

1.2.2 *Class 2*—Normalized and precipitation heat treated.

1.2.2.1 Available in Grade A only. Grade A has minimum specified tensile strength of 72 ksi for thinner plates and 65 and 60 ksi for thicker plates, with the minimum tensile strength dependent upon the plate thickness. The maximum thickness of Grade A, Class 2 is limited only by the capacity of the chemical composition and heat treatment to meet the specified mechanical property requirements; however, current practice usually limits the maximum thickness to 8 in. [200 mm].

1.2.3 *Class 3*—Quenched and precipitation heat treated.

1.2.3.1 Available as Grade A with a minimum specified tensile strength of 85 ksi for thinner plates and 75 and 70 ksi for thicker plates, with the minimum tensile strength dependent upon the plate thickness. The maximum thickness of Grade A, Class 3 plates is limited only by the capacity of the chemical composition and heat treatment to meet the specified mechanical property requirements; however, current practice usually limits the maximum thickness to 8 in. [200 mm].

1.2.3.2 Available as Grade C with a specified minimum tensile strength of 95 ksi for plates $^{3}/_{4}$ in. [20 mm] and under in thickness and 90 ksi for plates over $^{3}/_{4}$ in. in thickness. The maximum thickness of Grade C, Class 3, plates is 2 in. [50 mm].

1.3 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished in inch-pound units.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of

the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this specification shall conform to the requirements of Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and weight, quality, repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for compliance to the basis of purchase when purchasing material to this specification.

3.3 Certain supplementary requirements considered suitable for use with this specification are listed at the end of this specification. These include some of the standardized supplementary requirements listed in Specification A 20/A 20M as well as additional ones unique to this specification.

4. Manufacture

4.1 The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 *Class 1*—The material shall be precipitation heat treated at a temperature in the range from 1000 to 1300°F [540 to 705°C] for a time to be determined by the material manufacturer.

5.2 *Class 2*—The material shall be normalized at a temperature in the range from 1600 to 1700°F [870 to 930°C] and then precipitation heat treated at a temperature in the range from 1000 to 1300°F [540 to 705°C] for a time to be determined by the material manufacturer.

5.3 *Class 3*—The material shall be quenched in a liquid medium from a temperature in the range from 1600 to 1700°F [870 to 930°C] and then precipitation heat treated at a temperature in the range from 1000 to 1300°F [540 to 705°C] for a time to be determined by the material manufacturer.

5.4 If the purchaser elects to perform the thermal treatment, the material shall be accepted on the basis of mill tests from test coupons heat treated in accordance with the purchase order requirements. If the test coupon heat treatment requirements are not indicated on the purchase order, the manufacturer shall heat treat the test coupons under conditions he considers appropriate. The manufacturer shall inform the purchaser of the procedure followed in thermally treating the test coupons at the mill.

6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

7. Mechanical Requirements

7.1 *Tension Test Requirements*—The material as represented by the tension test specimens shall conform to the requirements shown in Table 2.

7.1.1 For nominal plate thicknesses of $\frac{3}{4}$ in. [20 mm] and under, the $1\frac{1}{2}$ in. [40 mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation.

7.2 *Notch Toughness Test Requirements:*

7.2.1 Charpy V-notch impact tests shall be made in accordance with Specification A 20/A 20M.

7.2.2 The test results of 10 by 10 mm specimens shall meet an average minimum value of 20 ft·lbf [27 J] at −50°F [−45°C].

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %	
	Grade A	Grade C
Carbon, max		
Heat analysis	0.07	0.07
Product analysis	0.09	0.090
Manganese		
Heat analysis	0.40–0.70	1.30–1.65
Product analysis	0.35–0.78	1.21–1.77
Phosphorus, max[A]	0.025	0.025
Sulfur, max[A]	0.025	0.025
Silicon, max		
Heat analysis	0.40	0.40
Product analysis	0.45	0.45
Chromium		
Heat analysis	0.60–0.90	. . .
Product analysis	0.56–0.94	. . .
Nickel		
Heat analysis	0.70–1.00	0.70–1.00
Product analysis	0.67–1.03	0.67–1.03
Molybdenum		
Heat analysis	0.15–0.25	0.15–0.25
Product analysis	0.12–0.28	0.12–0.28
Copper		
Heat analysis	1.00–1.30	1.00–1.30
Product analysis	0.95–1.35	0.95–1.35
Columbium, min		
Heat analysis	0.02	0.02
Product analysis	0.01	0.01

[A] Applies to both heat analysis and product analysis.

TABLE 2
TENSILE REQUIREMENTS

	Grade A Class 1, ksi [MPa]	Grade A Class 2, ksi [MPa]	Grade A Class 3, ksi [MPa]	Grade C Class 1, ksi [MPa]	Grade C Class 3, ksi [MPa]
Yield strength, min					
3/4 in. and under	80	65	75	90	85
[20 mm and under]	[550]	[450]	[515]	[620]	[585]
Over 3/4 to 1 in., incl	. . .	65	75	. . .	80
[Over 20 to 25 mm, incl]	. . .	[450]	[515]	. . .	[550]
Over 1 to 2 in., incl	. . .	60	75	. . .	80
[Over 25 to 50 mm, incl]	. . .	[415]	[515]	. . .	[550]
Over 2 to 4 in., incl	. . .	55	65	. . .	. . .
[Over 50 to 100 mm, incl]	. . .	[380]	[450]	. . .	. . .
Over 4 in.	. . .	50	60	. . .	. . .
[Over 100 mm]	. . .	[345]	[415]	. . .	. . .
Tensile strength					
3/4 in. and under	90–110	72–92	85–105	100–120	95–115
[20 mm and under]	[620–760]	[495–635]	[585–725]	[690–825]	[655–795]
Over 3/4 to 1 in., incl	. . .	72–92	85–105	. . .	90–110
[Over 20 to 25 mm, incl]	. . .	[495–635]	[585–725]	. . .	[620–760]
Over 1 to 2 in., incl	. . .	72–92	85–105	. . .	90–110
[Over 25 to 50 mm, incl]	. . .	[495–635]	[585–725]	. . .	[620–760]
Over 2 to 4 in., incl	. . .	65–85	75–95	. . .	. . .
[Over 50 to 100 mm, incl]	. . .	[450–585]	[515–655]	. . .	. . .
Over 4 in.	. . .	60–80	70–90	. . .	. . .
[Over 100 mm]	. . .	[415–550]	[485–620]	. . .	. . .
Elongation					
in 2 in. [50 mm], min, %	20[A]	20[A]	20[A]	20[A]	20[A]

[A] See Specification A 20/A 20M.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed in this section by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post Weld Heat Treatment of Mechanical Test Coupons,

S4. Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop-Weight Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S10. Charpy V-Notch Test Curve,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S13. NDT Temperature Determination,

S14. Bend Test,

S15. Reduction of Area Measurement,

S17. Vacuum Carbon-Deoxidized Steel,

S19. Restricted Chemical Requirements,

S24. Strain Age Test, and

S25. Weldability.

SPECIFICATION FOR PRESSURE VESSEL PLATES, HIGH-STRENGTH, LOW-ALLOY STEEL

SA-737/SA-737M

[Identical with ASTM Specification A 737/A 737M-87 (Reapproved 1991)]

1. Scope

1.1 This specification covers high-strength low-alloy steel plates for service in welded pressure vessels and piping components.

1.2 This material is particularly intended for piping and pressure vessel applications where high strength and improved toughness are required.

1.3 Two grades, designated B and C, are covered by this specification. Grade B provides a minimum yield strength of 50 ksi [345 MPa]. Grade C provides a minimum yield strength of 60 ksi [415 MPa].

1.4 The maximum thickness of plates is limited only by the capacity of the chemical composition and heat treatment to meet the specified mechanical property requirements. Individual manufacturers should be consulted on thickness limitations since current industry limitations have not been ascertained to date.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in noncomformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this specification shall conform to the requirements of Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality, repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for compliance to the ordering information when purchasing material to this specification.

3.3 Certain supplementary requirements considered suitable for use with this specification are listed at the end of the specification. These include some of the standardized supplementary requirements listed in Specification A 20/A 20M as well as additional ones unique to this specification.

4. Manufacture

4.1 *Steelmaking Practice:*

4.1.1 The steel may be made by any of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4.1.2 The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 The material shall be normalized by heating to a suitable temperature which produces an austenitic structure, but not exceeding 1700°F [925°C], holding a sufficient time to attain uniform heat throughout the material, and cooling in air.

5.2 If approved by the purchaser, cooling rates faster than air cooling are permitted for improvement of strength or toughness, provided the plates are subsequently tempered in the temperature range from 1100 to 1300°F [595 to 705°C].

5.3 If the purchaser elects to perform the required heat treatment, the material shall be accepted on the basis of mill tests made from test coupons heat treated in accordance with the purchase order requirements. If the test coupon heat-treatment requirements are not indicated on the purchase order, the manufacturer shall heat treat the test coupons under conditions he considers appropriate. The manufacturer shall inform the purchaser of the heat-treatment procedure followed in heat treating the test coupon at the mill.

6. Chemical Requirements

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Tests*—The material as represented by the tension test specimens shall conform to the requirements shown in Table 2.

7.1.1 For nominal plate thicknesses of $\frac{3}{4}$ in. [20 mm] and under, when requirements for elongation in 2 in. [50 mm] are to be determined, the $1\frac{1}{2}$ in. [40 mm] wide rectangular specimen may be used for the tension test, and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and that shows the greatest elongation.

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %			
	Grade B		Grade C	
Element	Heat	Product	Heat	Product
Carbon, max	0.20	0.22	0.22	0.24
Manganese	1.15–1.50[B]	1.07–1.62[B]	1.15–1.50	1.07–1.62
Phosphorus, max	0.035	0.035	0.035	0.035
Sulfur, max	0.030	0.035	0.030	0.035
Silicon	0.15–0.50	0.10–0.55	0.15–0.50	0.10–0.55
Vanadium	. . .	. . .	0.04–0.11	0.03–0.12
Columbium, max	0.05	0.05	[A]	. . .
Nitrogen, max	. . .	. . .	0.03	0.03

[A] Columbium may be present in the amount of 0.05 maximum.
[B] The maximum manganese may be increased to 1.60% on heat analysis and 1.72% on product analysis, provided that the carbon content on heat analysis does not exceed 0.18%.

TABLE 2
TENSILE REQUIREMENTS

	Grade B	Grade C
Yield strength, min, ksi [MPa]	50 [345]	60 [415]
Tensile strength, ksi [MPa]	70–90 [485–620]	80–100 [550–690]
Elongation in 8 in. [200 mm], min, %	18[A]	18[A]
Elongation in 2 in. [50 mm], min, %	23[A]	23[A]

[A] See Specification A 20/A 20M.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed below by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Tests, and

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR PRESSURE VESSEL PLATES, HEAT-TREATED, CARBON-MANGANESE-SILICON STEEL, FOR MODERATE AND LOWER TEMPERATURE SERVICE

SA-738/SA-738M

(Identical with ASTM Specification A 738/A 738M-90.)

1. Scope

1.1 This specification covers heat-treated carbon-manganese-silicon steel plates intended for use in welded pressure vessels at moderate and lower temperature service.

1.2 Material under this specification is available in three strength levels, 75 ksi [515 MPa], 85 ksi [585 MPa], and 80 ksi [550 MPa], minimum ultimate tensile strengths.

1.3 The maximum thickness of Grade A plates is limited only by the capacity of the chemical composition and heat treatment to meet the specified mechanical property requirements. The maximum thickness of Grade B plates is limited to 2.5 in. [65 mm]. The maximum thickness of Grade C is limited to 6 in.

1.4 Grade A is the material that, prior to 1984, was covered by Specification A 738 without a grade designation.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standards. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Document

2.1 *ASTM Standard:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this specification shall conform to the requirements of Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality, repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for compliance to the ordering information when purchasing material to this specification.

3.3 Certain supplementary requirements considered suitable for use with this specification are listed at the end of the specification. These include some of the standardized supplementary requirements listed in Specification A 20/A 20M as well as additional ones unique to this specification.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

5. Heat Treatment

5.1 Grade A plates 2.5 in. [65 mm] and under in thickness shall be supplied in either the normalized or quenched and tempered condition.

5.2 Grade A plates over 2.5 in. [65 mm] in thickness and Grade B and Grade C plates in all thicknesses shall be quenched-and-tempered.

5.3 When plates are tempered, the minimum tempering temperature shall be 1100°F [595°C].

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements* — The material as represented by the tension test specimens shall conform to the requirements of Table 2.

7.1.1 For nominal plate thicknesses of $^{3}/_{4}$ in. [20 mm] and under, the 1.5 in. [40 mm] wide rectangular specimen may be used for the tension test and the elongation may be determined in a 2 in. [50 mm] gage length that includes the fracture and shows the greatest elongation.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max[A]	0.24	0.20	0.20
Manganese:			
Heat analysis			
2.5 in. [65 mm] and under	1.50 max	0.90–1.50	1.50
Over 2.5 in. [65 mm]	1.60 max	. . .	1.60 max
Product analysis			
2.5 in. [65 mm] and under	1.62 max	0.84–1.62	1.62 max
Over 2.5 in. [65 mm]	1.72 max	. . .	1.72 max
Phosphorus, max[A]	0.035	0.030	0.025
Sulfur, max[A]	0.035	0.030	0.025
Silicon:			
Heat analysis	0.15–0.50	0.15–0.55	0.15–0.50
Product analysis	0.13–0.55	0.13–0.60	0.13–0.55
Copper, max:			
Heat analysis	0.35	0.35	0.35
Product analysis	0.38	0.38	0.38
Nickel, max:			
Heat analysis	0.50	0.60	0.50
Product analysis	0.53	0.63	0.53
Chromium, max:			
Heat analysis	0.25	0.30	0.25
Product analysis	0.29	0.34	0.29
Molybdenum, max:			
Heat analysis			
1.5 in. [40 mm] and under	0.08	0.20	0.08
Over 1.5 in. [40 mm]	0.08	0.30	0.08
Product analysis			
1.5 in. [40 mm] and under	0.09	0.21	0.09
Over 1.5 in. [40 mm]	0.09	0.33	0.09
Vanadium, max:			
Heat analysis	0.07[B]	0.07	0.05
Product analysis	0.08[B]	0.08	0.05
Columbium, max:			
Heat analysis	0.04[B]	0.04	. . .
Product analysis	0.05[B]	0.05	. . .
Columbium plus Vanadium, max:			
Heat analysis	0.08[B]	0.08	. . .
Product analysis	0.10[B]	0.10	. . .

[A] Applies to both heat and product analyses.
[B] Vanadium and columbium may be added only by agreement between the producer and the purchaser.

TABLE 2
TENSILE REQUIREMENTS

	Grade A ksi [MPa]	Grade B ksi [MPa]	Grade C ksi [MPa]
Tensile strength			
t^A = 2.5 in. & under	75–95	86–102	80–100
[t = 65 mm & under]	[515–655]	[585–705]	[550–590]
t = Over 2.5 to 4 in. incl	75–95	. . .	75–95
[t = Over 65 mm to 100 mm incl]	[515–655]	. . .	[515–655]
t = Over 4 to 6 in. incl	75–95	. . .	70–90
[t = Over 100 to 150 mm incl]	[515–655]	. . .	[485–620]
Yield strength, min			
t = 2.5 in. & under	45	60	60
[t = 65 mm & under]	[310]	[415]	[415]
t = Over 2.5 to 4 in. incl	45	. . .	55
[t = Over 65 mm to 100 mm incl]	[310]	. . .	[380]
t = Over 4 to 6 in. incl	45	. . .	46
[t = Over 100 to 150 mm incl]	[310]	. . .	[315]
Elongation in 2 in. [50 mm], min, %			
t = 4 in. & under	20	20	22
[t = 100 mm & under]	20	20	22
t = Over 4 in.	20	. . .	20
[t = Over 100 mm]	20	. . .	20

[A] t = plate nominal thickness.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Several of those considered suitable for use with this specification are listed by title. Other tests may be performed by agreement between this specification are listed by title:

S2. Product Analysis.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons.

S4. Additional Tension Test.

S5. Charpy V-Notch Impact Test.

S6. Drop Weight Test.

S17. Vacuum Carbon-Deoxidized Steel.

S20. Maximum Carbon Equivalent for Weldability.

APPENDIX

(Nonmandatory Information)

X1. CHARPY V-NOTCH IMPACT TEST

X1.1 The energy values below are shown only for information as to the guarantees that are generally available. Mandatory conformance to any of the values listed is a matter of agreement between the purchaser and the manufacturer.

X1.1.1 *Longitudinal* — 20 ft·lbf [27 J] at −50°F [45°C].

X1.1.2 *Transverse* — 20 ft·lbf [27 J] at −20°F [30°C].

SPECIFICATION FOR STEEL BARS, ALLOY, HOT-WROUGHT, FOR ELEVATED TEMPERATURE OR PRESSURE-CONTAINING PARTS, OR BOTH

SA-739

[Identical with ASTM Specification A 739-90a (Reapproved 1995)$^{\epsilon 1}$.] 98

1. Scope

1.1 This specification covers hot-wrought, ferritic alloy steel bars for elevated temperature or pressure-containing parts suitable for fusion welding or both.

1.2 The bars are furnished in the following grades:

Grade B 11: 1.25% chromium, 0.55% molybdenum
Grade B 22: 2.25% chromium, 1.00% molybdenum

98 **1.3** The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

3. Ordering Information

3.1 Orders for material under this specification should include the following information:

3.1.1 Quantity (weight or number of pieces),

3.1.2 Name of material (ferritic alloy steel bars),

3.1.3 Condition (hot wrought, normalized and tempered, machine straightened and descaled),

3.1.4 Dimensions (cross-sectional shape, size, and length),

3.1.5 ASTM designation and date of issue,

3.1.6 Grade (Table 1),

3.1.7 Additions to the specification, and

3.1.8 End use.

NOTE 1 — A typical description is as follows: 10 000 lb, Ferritic Alloy Steel Bars, Hot Wrought Normalized and Tempered, and Descaled, 1.000-in. diameter by 10 ft, ASTM A 739 dated _____, Grade B 11, Special Straightened, Special Machined Fittings.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 29/A 29M.

5. Materials and Manufacture

5.1 *Melting Practice* — The steel shall be made by one or more of the following primary processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting using electroslag remelting or vacuum arc remelting. Where secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

5.2 *Condition* — Unless otherwise specified, bars shall be hot wrought, heat treated, and descaled.

5.3 *Heat Treatment:*

5.3.1 The bars shall be normalized and tempered.

5.3.2 Austenitizing temperature shall be within the range from 1700 to 1800°F (927 to 982°C).

5.3.3 Cooling from the austenitizing temperature may be accomplished by cooling in still air or moving air, at the producer's option. When permitted by the purchaser, cooling from the austenitizing temperature may be accelerated by spray or liquid quenching.

5.3.4 The minimum tempering temperature shall be 1200°F (649°C) for Grade B 11 and 1250°F (677°C) for Grade B 22.

6. Chemical Composition

6.1 The heat analysis shall conform to the limits for chemical composition specified in Table 1 for the grade ordered.

7. Mechanical Properties

7.1 *Tensile Requirements* — The bars as represented by the test specimens shall conform to the tensile requirements specified in Table 2.

7.2 *Specimens* — Tension test specimens shall be taken longitudinally and machined from the locations specified in Test Methods and Definitions A 370.

7.3 *Number of Tests:*

7.3.1 Two tension tests shall be made to represent bars of the same size from each heat in each heat treatment charge. For continuous heat-treated material, not fewer than two tension tests shall represent a lot selected on the basis of one tension test from each 10 000 lb (4500 kg).

7.3.2 When heat treated without interruption in continuous furnaces, the material in a lot shall be from the same heat, same prior condition, same size, and subjected to the same heat treatments.

7.4 *Test Methods* — Tension tests shall be made in accordance with Test Methods and Definitions A 370. The yield strength shall be determined by the 0.2% offset method.

8. Workmanship, Finish, and Appearance

8.1 *Workmanship* — The bars shall be free of pipe, cracks, and flakes. Within the limits of good manufacturing and inspection practices the bars shall be free of injurious seams, laps, segregation, or other imperfections which, due to their nature, degree or extent, will interfere with the use of the material in machining or fabrication.

8.2 *Descaling* — Unless otherwise specified, the bars shall be descaled.

9. Certification and Test Reports

9.1 A manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the analysis and tension test results shall be furnished at the time of shipment. The report shall include the name of the manufacturer, ASTM designation number and year date and revision letter, if any, grade, heat number, and size.

10. Product Marking

10.1 The bars shall be marked in accordance with Specification A 29/A 29M except as modified or supplemented by 10.2 through 10.4 of this specification.

10.2 When specified by the purchaser, the heat number shall be permanently stamped on one end of each bar 2.50 in. and larger in nominal diameter (or equivalent cross-sectional area.

10.3 The bars shall neither be hot nor cold stamped on the sides unless approved by the purchaser on the purchase order.

10.4 Each lift, regardless of size, shall be tagged with the information required by Specification A 29/A 29M.

11. Keywords 98

11.1 alloy steel bars; high-temperature applications; hot-wrought steel bars; pressure-containing parts; steel bars; temperature service application — high

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %	
	Grade B 11	Grade B 22
Carbon, max	0.05–0.20	0.05–0.15
Manganese	0.40–0.65	0.30–0.60
Phosphorus, max	0.035	0.035
Sulfur, max	0.040	0.040
Silicon	0.50–0.80	0.50 max
Chromium	1.00–1.50	2.00–2.50
Molybdenum	0.45–0.65	0.90–1.10

TABLE 2
TENSILE REQUIREMENTS

	Grade B 11	Grade B 22
Tensile strength, ksi (MPa)	70.0–95.0 (483–655)	75.0–95.0 (517–655)
Yield strength, min, ksi (MPa)	45.0 (310)	45.0 (310)
Elongation in 2 in. or 50 mm, min, %	18	18
Reduction of area, min, %	45	45

PRACTICE FOR ULTRASONIC EXAMINATION OF AUSTENITIC STEEL FORGINGS

SA-745/SA-745M

(Identical with ASTM Specification A 745/A 745M-94 except for the deletion of 1.5.) 98

1. Scope

1.1 This practice covers the standards and procedures for the contact, pulse-echo ultrasonic examination of austenitic steel forgings by the straight or angle beam techniques, or both.

98 **1.2** This practice shall be used whenever the inquiry, proposal, contract, order, or specification states that austenitic steel forgings are to be subject to ultrasonic examination in accordance with Practice A 745/A 745M. Ultrasonic examination of nonmagnetic retaining ring forgings should be made to Practice A 531, not to this practice.

1.3 The values stated in either inch-pound or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the practice.

1.4 This practice and the applicable material specifications are expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 DELETED

2. Referenced Documents

98 **2.1** *ASTM Standards:*

A 531 Practice for Ultrasonic Inspection of Turbine-Generator Steel Retaining Rings

E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments

E 428 Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection

2.2 *American Society for Nondestructive Testing Document:*

SNT-TC-1A Recommended Practice for Non-destructive Personnel Qualification and Certification

3. Ordering Information

3.1 When this practice is to be applied to an inquiry or purchase order, the purchaser shall furnish the following information:

3.1.1 Quality level of examination (see Section 12).

3.1.2 Additional requirements to this practice.

3.1.3 Applicability of supplementary requirements (see Supplementary Requirements section).

3.2 When specified, the manufacturer shall submit 98 an examination procedure for purchaser approval that shall include, but not be limited to a sketch of the configuration as presented for ultrasonic examination showing the surfaces to be scanned, scanning directions, notch locations and sizes (if applicable), extent of coverage (if applicable), and an instruction listing calibration and inspection details and stage of manufacture.

4. Apparatus

4.1 An electronic, pulsed, reflection type of instrument shall be used for this examination. The system shall

have a minimum capability for operating at frequencies from 0.5 to 5.0 MHz. Either video or r-f presentation is acceptable.

98 **4.2** The ultrasonic instrument shall provide linear presentation (within ±5% of the signal height) for at least 75% of the screen height (sweep line to top of screen). This 5% linearity is descriptive of the screen presentation of amplitude. Instrument linearity shall be verified in accordance with the intent of Practice E 317.

4.3 Instruments with incremental gain control (accurate over its useful range to ±10% of the nominal attenuation ratio) shall be used when possible to allow measurement of signals beyond the linear display range of the instrument.

4.4 *Search Units:*

4.4.1 Search units having transducers of either quartz or other piezoelectric materials may be employed.

4.4.2 The maximum nominal active area of $1\frac{1}{2}$ in.^{2} [970 mm^2] with $\frac{1}{2}$ in. [13 mm] minimum to $1\frac{1}{8}$ in. [30 mm] maximum dimensions or $\frac{3}{4}$ in. [20 mm] diameter minimum dimension shall be used for straight-beam scanning.

4.4.3 Angle-beam scanning transducers shall have a nominal active area of $\frac{1}{2}$ to 1 in.^{2} [325 to 650 mm^2]. The search unit used for angle-beam examination shall produce a beam angle of 30 to 70° in the material.

4.4.4 Other search units, including frequencies other than those listed in Section 8, may be used for evaluating and pinpointing indications of discontinuities.

4.5 *Couplant* — A suitable couplant having good wetting characteristics shall be used between the transducer and the examination surface. The same couplant shall be used for calibration and examination.

4.6 *Reference Blocks:*

98 **4.6.1** All ultrasonic standard reference blocks shall be in accordance with the general guidelines of Practice E 428. However, absolute conformance to Practice E 428 is not mandatory due to the nature of the material covered by this practice.

4.6.2 The reference block grain size, as measured by the relative acoustic penetrability of the reference blocks, should be reasonably similar to the forging under examination. However, it must be recognized that large austenitic forgings vary considerably in acoustic penetrability throughout their volume due to variations in grain size and structure. Reference blocks should be chosen that reasonably approximate the average penetrability of the forging under examination. Supplementary blocks of coarser or finer grain may be used for evaluation of indications as covered in Section 11.

4.6.3 As an alternative method, where practicable, the appropriate size of reference hole (or holes) or notches may be placed in representative areas of the forging for calibration and examination purposes when removed by subsequent machining. When holes or notches are not removed by subsequent machining, the purchaser must approve the location of holes or notches.

5. Personnel Requirements

5.1 Personnel performing the ultrasonic examinations 98 to this practice shall be qualified and certified in accordance with a written procedure conforming to Recommended Practice No. SNT-TC-1A or another national standard that is acceptable to both the purchaser and the supplier.

6. Forging Conditions

6.1 Forgings shall be ultrasonically examined after heat treating.

6.2 The surfaces of the forging to be examined shall be free of extraneous material such as loose scale, paint, dirt, etc.

6.3 The surface roughness of scanning surfaces shall not exceed 250 μin. [6 μm] unless otherwise stated in the order or contract.

6.4 The forgings shall be machined to a simple configuration, that is, rectangular or parallel or concentric surfaces where complete volumetric coverage can be obtained.

6.5 In certain cases, such as with contour forged 98 parts, it may be impractical to assure 100% volumetric coverage. Such forgings shall be examined to the maximum extent possible. A procedure indicating the extent of examination coverage shall be submitted for the purchaser's approval (see 3.2).

7. Procedure

7.1 Perform the ultrasonic examination after heat treatment when the forging is machined to the ultrasonic configuration but prior to drilling holes, cutting keyways, tapers, grooves, or machining sections to final contour.

7.2 To ensure complete coverage of the forging volume when scanning, index the search unit with at least 15% overlap with each pass.

7.3 The scanning rate shall not exceed 6 in. [150 mm]/s.

7.4 Scan all regions of the forging in at least two perpendicular directions to the maximum extent possible.

7.5 Scan disk and disk-type forgings using a straight beam from at least one flat face and radially from the circumference when practicable. For the purposes of this practice, a disk is a cylindrical shape where the diameter dimension exceeds the height dimension. Disk-type forgings made as upset-forged "pancakes" shall be classified as disks for inspection purposes although at the time of inspection, the part may have a center hole, counterturned steps, or other detail configuration.

7.6 Scan cylindrical sections, ring and hollow forgings from the entire external surface (sides or circumference), using the straight-beam technique, and scan the forging in the axial direction to the extent possible. When the length divided by the diameter ratio (slenderness ratio) exceeds 6 to 1 (or axial length exceeds 24 in. [600 mm]), scan axially from both end surfaces to the extent possible. If axial penetration is not possible due to attenuation, angle-beam examination directed axially may be substituted in place of axial straight beam. Examine ring and hollow forgings having an outside-diameter to inside-diameter ratio of less than 2 to 1 and a wall thickness less than 8 in. [200 mm] by angle-beam techniques from the outside diameter or inside diameter, or both, using full node or half-node technique (see 10.1.2 and 10.1.3) as necessary to achieve either 100% volumetric coverage or the extent of coverage defined by an approved procedure (see 3.2).

8. Examination Frequency

8.1 Perform all ultrasonic examination at the highest frequency practicable (as specified in 8.1.1, 8.1.2, or 8.1.3) that will adequately penetrate the forging thickness and resolve the applicable reference standard. Include in the ultrasonic examination report the examination frequency used. Determine the test frequency at the time of actual examination by the following guidelines:

8.1.1 The nominal test frequency shall be 2.25 MHz. Use of this frequency will generally be restricted due to attenuation.

8.1.2 One megahertz is acceptable and will be the frequency generally applicable.

8.1.3 When necessary, due to attenuation, 0.5 MHz examination frequency may be used. The purchaser may request notification before this lower frequency is employed.

8.1.4 In the event that adequate penetration of certain regions is not possible even at 0.5 MHz, alternative nondestructive examination methods (such as radiography) may be employed to ensure the soundness of the forging by agreement between the purchaser and the manufacturer.

9. Straight-Beam Examination

9.1 *Method of Calibration:*

9.1.1 Perform calibration for straight-beam examination on the flat-bottom hole size determined by the applicable quality level (see Section 12).

9.1.2 Determine the calibration method by the test metal distance involved.

9.1.2.1 Thicknesses up to 6 in. [150 mm] may be examined using either the single-block or the distance-amplitude curve calibration method.

(*a*) *Single-Block Method* — Establish the test sensitivity on the reference standard representing the forging thickness. Drill flat-bottom holes normal to the examining surface, to midsection in material up to 1.5 in. [40 mm] in thickness and at least 0.75 in. [20 mm] in depth but no deeper than midsection in thicknesses from 1.5 to 6 in. [40 to 150 mm]. Make evaluations of indications at the estimated discontinuity depth at which they are observed using supplementary reference standards, if necessary.

(*b*) *Distance-Amplitude-Curve Correction Method* — Establish the test sensitivity on the reference standard whose metal travel distance represents the greater metal travel distance of the part under examination, within ±1 in. [25 mm].

9.1.2.2 Examine thicknesses from 6 to 24 in. [150 to 600 mm] using the distance-amplitude calibration method. Calibration to ½ thickness test metal distance may be used provided examinations from two opposing surfaces are made.

9.1.2.3 For metal travel distances over 24 in. [600 mm], perform one of the following examinations:

(*a*) Perform a back-reflection examination from at least one surface to QL-5 (see 12.1.1) or to a purchaser-approved procedure (see 3.2).

(*b*) On hollow-round forgings with wall thicknesses less than 8 in. [200 mm], perform an axial angle-beam scan in place of the straight-beam scan from the end surfaces. Calibration for this scan may be established on the existing axial notches required for the circumferential scan or on transverse oriented notches installed specifically for axial angle beam.

9.2 *Calibration Procedure* — Over an indication-free area of the forging and with the proper test frequency, adjust the amplitude of the back reflection to the maximum limit of vertical linearity of the instrument. The adjusted instrument sensitivity display shall be the primary calibration reference for both the single-block and multiple-block calibration methods. If, at this gain setting, the amplitude response from the flat-bottom hole in the longest calibration block is not equal to or greater than 0.5 in. [13 mm] sweep-to-peak, adjust the instrument gain further to obtain a 0.5 in. [13 mm] sweep-to-peak minimum response. To complete the distance-amplitude correction curve, determine the remaining points defining the shape of the curve at this adjusted gain setting and mark the curve on the shield of the cathode ray tube or plot on a graph. At least three blocks shall be used with test metal distances of 3 in. [75 mm] $\frac{1}{2}$ *T*, and *T*. However, the distance between any of the test blocks shall be $1\frac{1}{2}$ in. [40 mm] minimum. If indications closer than 3 in. [75 mm] from the initial pulse must be evaluated, an additional block with $1\frac{1}{2}$ in. [40 mm] test metal distance shall be used. This is the fixed reference against which all indications shall be evaluated at the maximum obtainable response at whatever depth the indications are observed. This will constitute an acceptable examination if there are no indications exceeding the acceptance limits. In large forgings, it is expected that a portion of the distance-amplitude curve will be above the vertical linearity limits of the instrument. If an indication appears in this area, readjust the instrument through the use of a calibrated gain control or through recalibration to the initial calibration level to bring the appropriate portion of the presentation on screen for evaluation of that specific area.

NOTE 1 — When flat surfaced reference block calibration is used for examination of forgings with surface curvature, compensation for curvature shall be made and the method for curvature correction shall be a matter of agreement between the producer and the purchaser. For diameters 80 in. [2000 mm] and over, no correction factor is required.

10. Angle-Beam Examination

10.1 Ring and hollow round forgings, as defined in 7.6, shall be angle-beam examined from their outer periphery in both circumferential directions employing the following method of calibration:

10.1.1 Notches of 1.25 in. [30 mm] maximum surface length, with the length perpendicular to sound propagation; depth based on quality level (Section 12), either rectangular with a width not greater than twice its depth or 60° minimum to 75° maximum included angle, located in the forging so as to produce no interference with each other, shall be used as calibration standards.

10.1.2 Determine the response from the inside and outside diameter calibration notches with the search unit positioned to produce the maximum response from each notch. Adjust the sensitivity of the ultrasonic equipment so that the indication from the notch at the greatest test metal distance is at least 0.5 in. [13 mm] sweep-to-peak. Draw a straight line connecting the peaks of the responses obtained from the inside and outside diameter notches. This shall be the primary reference line. This procedure is considered full node calibration.

10.1.3 In the event that a response of at least 0.5 in. [13 mm] sweep-to-peak cannot be obtained from both the inside and outside diameter notches, calibrate from both the outer periphery (the outside diameter surface) and the inside diameter surface. Adjust the sensitivity of the ultrasonic equipment so that the indication from the notch in the opposite surface is at least 0.5 in. [13 mm] sweep-to-peak in magnitude. This procedure is considered half-node calibration. Axial angle beam may be substituted for straight beam from the end surfaces, when specified.

NOTE 2 — Long cylinders or cylinders with small inside diameters are difficult to examine from the inside diameter surface. Normally, neither inside diameters smaller than 18 in. [450 mm] nor long cylinders exceeding 36 in. [900 mm] in length are scanned from the inside diameter surface.

11. Evaluation of Material

11.1 Coarse-grained austenitic materials frequently display sweep noise, particularly when an examination is performed at high sensitivities. For this reason, it is important to critically scrutinize reportable and rejectable indications to determine whether they result from defects or grain structure. It is desirable to have

several sets of calibration blocks with varying degrees of grain coarseness so that the attenuation of the defective area can be reasonably matched with a test block for a more accurate minimum defect size estimation. Due to the normal wide variation in attenuation throughout a given large austenitic forging, it is permissible to evaluate rejectable indications on the basis of alternative calibration blocks that compare more reasonably in attenuation to the defect area. It is also permissible to insert reference holes into representative areas of the forging itself, with the approval of the purchaser, to be used for calibration and evaluation of indications. Loss of back reflection results not only from internal discontinuities but also from coarse or nonuniform grain structures, variations in coupling, nonparallel reflecting surfaces, and other factors that must be considered before concluding that loss of back reflection resulted from discontinuities.

12. Quality Levels for Acceptance

12.1 One of the following quality levels may be specified by the purchaser:

12.1.1 *Straight Beam:*

12.1.1.1 Material producing an indication response whose maximized amplitude equals or exceeds 100% of the primary reference or distance-amplitude correction curve at the estimated discontinuity depth shall be considered unacceptable.

(*a*) *QL-1* — A distance-amplitude curve shall be based upon the amplitude response from No. 8 flat-bottom hole ($^{8}/_{64}$ in. [3 mm]).

(*b*) *QL-2* — A distance-amplitude curve shall be based upon the amplitude response from No. 16 flat-bottom hole ($^{16}/_{64}$ in. [6 mm]).

(*c*) *QL-3* — A distance-amplitude curve shall be based upon the amplitude response from No. 24 flat-bottom hole ($^{24}/_{64}$ in. [10 mm]).

(*d*) *QL-4* — A distance-amplitude curve shall be based upon the amplitude response from No. 32 flat-bottom hole ($^{32}/_{64}$ in. [13 mm]).

(*e*) *QL-5* — A back reflection examination shall be performed guaranteeing freedom from complete loss of back reflection accompanied by an indication of a discontinuity. For this purpose, a back reflection of less than 5% of full screen height shall be considered complete loss of back reflection.

12.1.1.2 The applicable quality level will necessarily vary with test metal distance, purchasers' requirements, and the type and size of forging involved. Large disks, rings, or solid forgings and complex forgings present extraordinary problems and quality level application shall be a matter of agreement between the manufacturer and the purchaser. For general guidance purposes, the following list of test metal distances versus quality level attainable is provided for general information.

(*a*) *QL-1* — Generally practical for thicknesses up to 3 in. [75 mm].

(*b*) *QL-2* — Generally practical for thicknesses up to 8 in. [200 mm].

(*c*) *QL-3* — Generally practical for thicknesses up to 12 in. [300 mm].

(*d*) *QL-4* — Generally practical for thicknesses up to 24 in. [600 mm].

(*e*) *QL-5* — Frequently practical for thicknesses over 24 in. [600 mm].

12.1.2 *Angle Beam* — Material producing indications with amplitudes equal to or exceeding the primary reference-acceptance line (full node calibration: see 10.1.2) at the estimated discontinuity depth observed shall be considered unacceptable. When examining with only one calibration notch (half node calibration: see 10.1.3), material containing indications of discontinuities equal to or exceeding the notch indication amplitude shall be considered unacceptable.

12.1.2.1 *QA-1* Angle beam reference acceptance shall be based on a notch depth of 3% of the thickness of the forging at the time of examination.

12.1.2.2 *QA-2* Angle beam reference acceptance line shall be based on a notch depth of the lesser of 5% of the thickness of the forging at the time of inspection, or $^{3}/_{4}$ in. [19.05 mm].

13. Reportable Indications

13.1 A record that shows the location and orientation of all indications or groups of indications with amplitudes as defined below shall be submitted to the purchaser for information.

13.1.1 Indications accompanied by a loss of back reflection of 75% of screen height. Similar loss in back reflection without indications shall be scanned at lower frequencies; if unsuccessful, the area shall be reported as "not inspected."

13.1.2 Indications distinct from the normal noise level and traveling to the left or right on the cathode ray tube with movement of the transducer 1.0 in. [25 mm] or more over the surface of the forging.

13.1.3 Indications equal to or exceeding 50% of the applicable reference acceptance curve (both straight and angle beam).

98 14. Keywords

14.1 acceptance criteria; austenitic forgings; contact method; ultrasonic examination

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Angle Beam Calibration Based on Final Thickness

S1.1 The depth of the calibration notch (see 12.1.2) shall be based upon the final ordered thickness of the forging rather than the thickness at the time of inspection.

SPECIFICATION FOR PRECIPITATION HARDENING STAINLESS STEEL CASTINGS

SA-747/SA-747M

(Identical to ASTM Specification A 747/A 747M-93.) 98

1. Scope

1.1 This specification covers iron-chromium-nickel-copper corrosion-resistant steel castings, capable of being strengthened by precipitation hardening heat treatment.

1.2 These castings may be used in services requiring corrosion resistance and high strengths at temperatures up to 600°F, [315°C]. They may be machined in the solution-annealed condition and subsequently precipitation hardened to the desired high-strength mechanical properties specified in Table 1 with little danger of cracking or distortion.

1.3 The material is not intended for use in the solution-annealed condition.

NOTE — If the service environment in which the material is to be used is considered conducive to stress-corrosion cracking, precipitation hardening should be performed at a temperature that will minimize the susceptibility of the material to this type of attack.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Methods and Definitions for Mechanical Testing of Steel Products

A 732/A 732M Specification for Castings, Investment, Carbon and Low-Alloy Steel, for General Application and Cobalt Alloy for High Strength at Elevated Temperatures

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use

E 38 Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys

E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys

2.2 *ASME Standard:*

ASME Boiler and Pressure Vessel Code, Supplementary Requirements S6, S14, and S27

3. General Conditions for Delivery

3.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

4. Ordering Information

4.1 Orders for material to this specification shall include the following:

4.1.1 Specification number and grade (Table 2).

4.1.2 Heat treatment condition (SA, H900, etc.), Table 3,

4.1.3 Drawing or pattern,

4.1.4 Options in the specification, if any, in accordance with 5.2, 6.3, and Section 7, and

4.1.5 Supplementary requirements, if any, including the standards of acceptance.

4.1.6 Notice when the castings are to be used in equipment covered by the ASME Boiler and Pressure Vessel Code, Supplementary Requirements S6, S14, and S27 are mandatory and must be specified in the purchase order.

5. Manufacture

5.1 The steel shall be made by the electric furnace process with or without separate refining such as argon-oxygen decarburization (AOD).

5.2 *Heat Treatment* — Castings may be given a homogenization heat treatment in accordance with 5.2.1 at the producer's option or when specified by the purchaser (see S26) prior to solution heat treatment. All castings whether homogenized or not, shall be given a solution treatment in accordance with 5.2.2 and unless ordered in the solution-annealed condition shall be precipitation hardened to the ordered condition, (Table 3).

5.2.1 Homogenization heat treatment shall consist of heating the castings and test material to a minimum of 1900°F (1040°C), holding for a minimum of 1½ h, and cooling to below 90°F (30°C).

5.2.2 Solution annealing heat treatment shall consist of heating the castings and test material to 1925°F (1050°C) ±50°F (30°C), holding the 30 min/in., (1.2 min/mm) of section but not less than 30 min, and cooling to below 90°F (30°C).

5.2.3 Temperature used for precipitation hardening shall be maintained within the range of ±25°F (±15°C) of that listed in Table 3 for the heat treatment condition ordered. (See Note).

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

6.2 When the H900 condition is ordered, the minimum columbium content (Table 2) shall not apply. It is recommended that columbium other than that in revert material not be added.

6.3 *Methods of Analysis* — Analytical procedures for nitrogen analysis are not included in Methods E 38 or Test Methods E 353, so if the contract or order specifies that the nitrogen content is to be reported, the method of analysis shall be agreed upon by purchaser and producer.

7. Repair by Welding

7.1 Repairs shall be made only in one of the following conditions: homogenized, solution annealed, H1100, H1150, H1150M, H1150DBL, or stress relieved at 1150°F ± 25°F [620°C ± 15°C] for a minimum of 4 h.

7.2 Castings welded in one of the aged conditions noted in 7.1 shall be post weld heat treated by the same aging treatment used prior to welding, or, where necessary to meet mechanical property requirements, shall be solution annealed and aged after welding. Castings welded in the stress-relieved condition shall receive the specification heat-treatment after welding.

TABLE 1
MECHANICAL PROPERTIES

Alloy Type	PH Heat Treatment	Hardness, HB, min	Yield Strength 0.2% Offset min, ksi (MPa)	Tensile Strength, ksi (MPa)	Elongation in 2 in. (51 mm), min, %[A]
CB7Cu-1	H900	375 min	145 [1000]	170 [1170]	5
	H925	375 min	150 [1035]	175 [1205]	5
	H1025	311 min	140 [965]	150 [1035]	9
	H1075	277 min	115 [795]	145 [100]	9
	H1100	269 min	110 [760]	135 [930]	9
	H1150	269 min	97 [670]	125 [860]	10
	H1150M	310 max	...	...	...
	H1150 DBL	310 max	...	...	...
CB7Cu-2	H900	375 min	145 [1000]	170 [1170]	5
	H925	375 min	150 [1035]	175 [1205]	5
	H1025	311 min	140 [965]	150 [1035]	9
	H1075	277 min	115 [795]	145 [1000]	9
	H1100	269 min	110 [760]	135 [930]	9
	H1150	269 min	97 [670]	125 [860]	10
	H1150M	310 max	...	...	...
	H1150 DBL	310 max	...	...	...

[A] If sub-size tension test bars are used, the gage length/gage diameter ratio must be 4 to 1 to assure elongation values comparable to those of the standard test specimen.

TABLE 2
CHEMICAL REQUIREMENTS[A]

	CB7Cu-1	CB7Cu-2
Carbon	0.07	0.07
Manganese	0.70	0.70
Phosphorus	0.035	0.35
Sulfur	0.03	0.03
Silicon	1.00	1.00
Chromium	15.50–17.70	14.0–15.50
Nickel	3.60–4.60	4.50–5.50
Copper	2.50–3.20	2.50–3.20
Columbium	0.15–0.35[C]	0.15–0.35[C]
Nitrogen[B]	0.05	0.05

[A] Limits are percent maximum unless shown as a range or stated otherwise.
[B] To be determined and reported when specified by the order or contract.
[C] See 6.2. When the H900 condition is ordered the minimum columbium content shall not apply.

TABLE 3
PRECIPITATION HARDENING HEAT TREATMENT[A,B]

Condition	PH[C] Temperature, °F (°C)	Time, h and min	Cooling Treatment
SA	Not precipitation hardened (see 5.2.3)		
H900	900 [480]	1.5	air cool
H925	925 [495]	1.5	air cool
H1025	1025 [550]	4.0	air cool
H1075	1075 [580]	4.0	air cool
H1100	1100 [595]	4.0	air cool
H1150	1150 [620]	4.0	air cool
H1150M	1400 [760]	2.0	air cool
	1150 [620]	4.0	air cool
H1150			
DBL	1150 [620]	4.0	air cool
	1150 [620]	4.0	air cool

[A] The furnace and controls used shall be calibrated and capable of uniformity of heating in order to ensure consistent results.
[B] See Note 1.
[C] ±25°F (15°C).

SUPPLEMENTARY REQUIREMENTS

A list of standardized supplementary requirements for use at the option of the purchaser is described in Specification A 781/A 781M. Those that are considered suitable for use with this specification are listed below by title only. Additional supplementary requirements suitable for use with this specification at the option of the purchaser are described below. One or more of the supplementary requirements indicated shall have the same force as if it were in the body of the specification. Supplementary Requirements details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S1. Magnetic Particle Examination

NOTE — When CB7Cu-1 alloy is inspected by magnetic particle method, false indications may be caused by ferrite stringers or traces of retained austenite in the microstructure. Liquid penetrant methods may be used to conform the presence or absence of a discontinuity when such indications are noted.

S2. Radiographic Examination

S3. Liquid Penetrant Examination

S5. Examination of Weld Preparation

S6. Certification

S13. Hardness Test

S13.1 Brinell hardness test shall be made from each heat treatment load for each heat. The results shall conform to the requirements in Table 1, and shall be reported to the purchaser or his representative.

S13.2 The test may be made on the end of the tension specimen unless the order requires it to be made on a casting, in which case, where possible, the test shall be made on a boss or extension located on the casting suitable for testing in the Brinell tester.

S13.3 The test shall be conducted in accordance with Methods A 370.

S14. Tension Test

S14.1 Tensile properties shall be determined from material representing each heat. The bar from which the test specimen is taken shall be heat treated with production castings to the same procedure as the castings it represents, unless the castings are ordered in the solution-annealed condition (5.2.2). The results shall conform to the requirements specified in Table 1 and shall be reported to the purchaser or his representative.

S14.2 When the contract or order specifies that the castings are to be furnished in the solution annealed condition, the manufacturer shall test specimens representing the castings which have been given the precipitation heat treatment specified by the purchaser in accordance with Table 3.

S14.3 Test coupons and tests shall be made in accordance with Test Methods and Definitions A 370. Where possible, the standard 2 in. [50 mm] gage length specimens shall be used, unless the purchase order is for investment castings. Standard subsize specimens may be used when a 2 in. gage length specimen is not feasible. When subsize specimens are used, the gage length shall be four times the gage diameter. When investment castings are ordered, the specimens shall be prepared in accordance with S3.2 of Specification A 732/A 732M.

S14.4 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same lot. A retest shall be allowed if the percentage elongation of any tension test specimen is less than that specified in Table 1, or if any part of the fracture is more than $\frac{3}{4}$ in. [19 mm] from the center of a standard 2 in. [50 mm] gage length established by scribe scratches on the untested specimen.

S26. Homogenization Heat Treatment

S26.1 The homogenization heat treatment shall consist of heating the castings and test material to a minimum of 1900°F (1040°C), holding for a minimum of $1\frac{1}{2}$ h, and cooling to below 90°F (30°C).

S27. Product Marking

S27.1 The manufacturer's name or identification mark and the pattern number shall be cast or stamped on all castings except those of such small size as to make such marking impractical. To minimize small defects caused by dislodged particles of molding sand, the number of cast identification marks should be minimized. When further specified, the heat numbers shall be marked on individual castings.

S27.2 When the castings are too small to mark individually, a symbol traceable to the lot shall be placed on the castings and the required identification then placed on a tag affixed to the container in which these castings are shipped.

SPECIFICATION FOR STATICALLY CAST CHILLED WHITE IRON-GRAY IRON DUAL METAL ROLLS FOR PRESSURE VESSEL USE

SA-748/SA-748M

(Identical with ASTM Specification A 748/A 748M-87.)

1. Scope

1.1 This specification covers statically cast dual metal rolls with the outer layer of the roll body being chilled white iron of different chemical composition than the core and journals of the roll which is gray cast iron. The castings are suitable for pressure containing parts, the design strength of which is based on the gray iron portion of the cylinder. The castings are suitable for service at temperatures up to 450°F [232°C].

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 278 Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F

A 278M Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 345°C [Metric]

A 667/A 667M Specification for Centrifugally Cast Dual Metal (Gray and White Cast Iron) Cylinders

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 ASTM designation and year of issue,

3.1.2 Dimensions of dual rolls,

3.1.3 Class of gray iron in the roll core (see 4.2),

3.1.4 Inspection requirements, if different (see 10.1),

3.1.5 Certification, if required (see 11.1), and

3.1.6 Special position of marking information, if required (see 12.1).

3.2 Any additional requirements not covered in this specification are subject to agreement between the manufacturer and purchaser.

4. Materials and Manufacture

4.1 The melting procedure shall be optional with the foundry.

4.2 The chilled white iron exterior of the roll body shall be made to a minimum hardness of 60 Scleroscope "C". The gray iron portion of the roll shall conform to the applicable class of Specifications A 278 and A 278M, as determined by design requirements. The scope of this specification shall include Nos. 20, 25, 30, and 35 of Specification A 278 [Nos. 150, 175, 200, and 250 of Specification A 278M].

4.3 The casting process shall be controlled to produce a metallurgical bond between the chilled white iron exterior and gray iron interior of the roll body.

5. Test Requirements

5.1 *Tensile Requirements*—Tensile bars removed from a prolongation at one end of the roll journal, in accordance with Specifications A 278 and A 278M, shall have a tensile strength not less than 80% of that specified by the applicable class of Specifications A 278 and A 278M.

5.2 *Thickness of Chilled White Iron:*

5.2.1 The thickness of the clear chilled white iron plus the mottled iron at the roll face shall not be more than 30% of the total finished wall thickness.

5.2.2 The thickness of the chilled white iron exterior of the roll body shall be determined by measuring the chill depth at the ends of the roll face.

6. Finish

6.1 All surfaces shall be machined or ground, or both, prior to the rolls being placed into service.

7. Number of Tests

7.1 The number of tension tests shall be in accordance with Specifications A 278 and A 278M.

8. Specimen Preparation

8.1 Test bars representing the gray iron portion of the roll shall be made from a prolongation at one end of the roll journal in accordance with Specifications A 278 and A 278M. Tension test specimens machined from this prolongation shall conform to the dimensions shown for Specimen "C" in Specifications A 278 and A 278M.

9. Test Method

9.1 Tension test specimens shall fit the holders of the testing machine in such a way that the load shall be axial. The use of self-aligning shackles is suggested. After reaching a stress equivalent to 15 000 psi [100 MPa], the speed of the moving head of the testing machine shall not exceed $\frac{1}{8}$ in. [3.2 mm]/min.

10. Inspection

10.1 The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. Unless otherwise specified, all tests and inspections shall be made at the place of manufacture prior to the shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

11. Acceptance and Certification

11.1 Final acceptance of the casting shall follow complete machining of the casting. Upon request of the purchaser and when so specified in the purchase order, a certification shall be made on the basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report or a statement by the supplier, accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with the provisions of this specification. Each certification so furnished shall be signed by an authorized agent of the supplier or manufacturer.

12. Product Marking

12.1 Pressure-containing castings made in accordance with this specification shall have the name of the manufacturer or his recognized trademark and the class of iron to which it conforms, cast or indelibly stamped on the surface indicated by the purchaser or in such a position as not to injure the usefulness of the casting.

SPECIFICATION FOR TEST METHODS, PRACTICES, AND TERMINOLOGY FOR CHEMICAL ANALYSIS OF STEEL PRODUCTS

SA-751

(Identical with ASTM Specification A 751-95.) 98

1. Scope

1.1 This standard covers definitions, reference methods, practices, and guides relating to the chemical analysis of steel, stainless steel, an related alloys. It includes both wet chemical and instrumental techniques.

1.2 Directions are provided for handling chemical requirements, product analyses, residual elements, and reference standards, and for the treatment and reporting of chemical analysis data.

1.3 This standard applies only to those product standards which include this standard or parts thereof as a requirements.

1.4 In cases of conflict, the product specification requirements shall take precedence over the requirements of this standard.

1.5 Attention is directed to Practice A 880 when there may be a need for information on criteria for evaluation of testing laboratories.

1.6 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 880 Practice for Criteria for Use in Evaluation of Testing Laboratories and Organizations for the Examination and Inspection of Steel, Stainless Steel, and Related Alloys

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specification

E 30 Methods for Chemical Analysis of Steel, Cast Iron Open-Hearth Iron, and Wrought Iron

E 50 Practice for Apparatus, Reagents, and Safety Precautions for Chemical Analysis of Metals

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition

E 60 Practice for Photometric and Spectrophotometric Methods for Chemical Analysis of Metals

E 212 Test Method for Spectrographic Analysis of Carbon and Low-Alloy Steel by the Rod-to-Rod Technique

E 322 Test Method for X-Ray Emission Spectrometric Analysis of Low-Alloy Steels and Cast Irons

E 327 Test Method for Optical Emission Spectrometric Analysis of Stainless Type 18-8 Steels by the Point-to-Plane Technique

E 350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

E 352 Test Methods for Chemical Analysis of Tool Steels and Other Similar Medium- and High-Alloy Steels

E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys

E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

E 403 Test Method for Optical Emission Spectrometric Analysis of Carbon and Low-Alloys Steel by the Point-to-Plane Technique

E 404 Test Method for Spectrographic Determination of Boron in Carbon and Low-Alloy Steel by the Point-to-Plane Technique
E 415 Method for Optical Emission Vacuum Spectrometric Analysis of Carbon and Low-Alloy Steel
E 421 Test Method for Spectrographic Determination of Silicon and Aluminum in High-Purity Iron
E 485 Test Method for Optical Emission Vacuum Spectrometric Analysis of Blast Furnace Iron by the Point-to-Plane Technique
E 572 Method for X-Ray Emission Spectrometric Analysis of Stainless Steel
E 663 Practice for Flame Atomic Absorption Analysis
E 882 Guide for Accountability and Quality Control in the Chemical Analysis Laboratory
E 1019 Methods for Determination of Carbon, Sulfur, Nitrogen, Oxygen, and Hydrogen in Steel and in Iron, Nickel, and Cobalt Alloys
E 1024 Guide for Chemical Analysis of Metals and Metal Bearing Ores by Flame Atomic Absorption Spectrophotometry
E 1063 Test Method for X-Ray Emission Spectrometric Determination of Cerium and Lathanum in Carbon and Low-Alloy Steels
E 1086 Test Method for Optical Emission Vacuum Spectrometric Analysis of Stainless Steel by the Point-to-Plane Excitation Technique
E 1087 Practice for Sampling Molten Steel from a Ladle Using An Immersion Sampler to Produce a Specimen for Emission Spectrochemical Analysis
E 1097 Guide for Direct Current Plasma Emission Spectrometry Analysis
E 1184 Practice for Electrothermal (Graphite Furnace) Atomic Absorption Analysis
E 1282 Guide for Specifying the Chemical Compositions and Selecting Sampling Practices and Quantitative Analysis Methods for Metals and Alloys
E 1329 Practice for Verification and the Use of Control Charts in Spectrochemical Analysis

3. Terminology

3.1 *Definitions — Pertaining to Analyses:*

3.1.1 *cast or heat (formerly ladle) analysis* — applies to chemical analyses representative of a heat of steel as reported to the purchaser and determined by analyzing a test sample, preferable obtained during the pouring of the steel, for the elements designated in a specification.

3.1.2 *product, check or verification analysis* — a chemical analysis of the semifinished or finished product, usually for the purpose of determining conformance to the specification requirements. The range of the specified composition applicable to product analysis is normally greater than that applicable to heat analysis in order to take into account deviations associated with analytical reproducibility (Note 1) and the heterogeneity of the steel.

NOTE 1 — The chemical analysis procedures in Methods E 350, E 352, E 353, E 354, and E 1019 include precision statements with regard to reproducibility data.

3.1.3 *product analysis tolerances* (Note 2) — a permissible variation over the maximum limit or under the minimum limit of a specified element and applicable only to product analyses, not cast or heat analyses.

NOTE 2 — The term "analysis tolerance" is often misunderstood. It does not apply to cast or heat analyses determined to show conformance to specified chemical limits. It applies only to product analysis and becomes meaningful only when the heat analysis of an element falls close to one of the specified limits. For example, stainless steel UNS 30400 limits for chromium are 18.00 to 20.00%. A heat that the producer reported as 18.01% chromium may be found to show 17.80% chromium by a user performing a product analysis. If the product analysis tolerance for such a chromium level is 0.20%, the product analysis of 17.80% chromium would be acceptable. A product analysis of 17.79% would not be acceptable.

3.1.4 *proprietary analytical method* — a nonstandard analytical method, not published by ASTM, utilizing reference standards traceable to the National Institute of Standards and Technology (NIST) (when available) or other sources referenced in Section 10.

3.1.5 *referee analysis* — performed using ASTM methods listed in 9.1.1 and NIST reference standards or methods and reference standards agreed upon between parties. The selection of a laboratory to perform the referee analysis shall be a matter of agreement between the supplier and the purchaser.

3.1.6 *certified reference material* — a specimen of material specially prepared, analyzed, and certified for chemical content under the jurisdiction of a recognized standardizing agency or group, such as the National Institute of Standards and Technology, for use by analytical laboratories as an accurate basis for comparison. Reference samples should bear sufficient resemblance to the material to be analyzed so that no significant differences are required in procedures or corrections (for example, for interferences or inter-element effects).

3.1.7 *working reference materials* — reference materials used for routine analytical control and traceable to NIST standards and other recognized standards when appropriate standards are available.

3.1.8 *Pertaining to Elements:*

3.1.9 *intentionally added unspecified element* — an element added in controlled amounts at the option of the producer to obtain desirable characteristics.

3.1.10 *residual element* — a specified or unspecified element, not intentionally added, originating in raw materials, refractories, or air.

3.1.11 *specified element* — an element controlled to a specified range, maximum or minimum, in accordance with the requirements of the product specification.

3.1.12 *trace element* — a residual element that may occur in very low concentrations, generally less than 0.01%.

4. Concerning the Specification of Chemical Composition Requirements

4.1 It is recommended that Guide E 1282 be consulted as a guide for specifying the chemical compositions for steels.

4.2 The recommended practice for specifying chemical composition limits is to limit the number of significant figures for each element so that the number of figures to the right of the decimal point conforms to the following:

Chemical Concentration		Maximum Number of Figures to the Right of the Decimal Point
Up to 0.010%	—	0.XXXX or may be expressed as ppm
Up to 0.10%	—	0.XXX
0.10 to 3.00%	—	0.XX
Over 3.0%	—	0.X

4.3 For those cases in which the composition range spans either 0.10 or 3.0%, the number of figures to the right of the decimal is to be determined by that indicated by the upper limit.

4.4 Technical considerations may dictate the employment of less than the number of figures to the right of the decimal as previously recommended.

NOTE 3 — The recommendations should be employed to reduce the number of significant figures, such as from 18.00 to 18.0%, but a significant figure should never be added unless there is a technical reason for so doing.

5. Cast or Heat Analysis

5.1 The producer shall perform analyses for those elements specified in the material specification. The results of such analyses shall conform to the requirements specified in the material specification.

5.1.1 For multiple heats, either individual heat or cast analysis or an average heat or cast analysis shall be reported. If significant variations in heat or cast size are involved, a weighted average heat or cast analysis, based on the relative quantity of metal in each heat or cast, shall be reported.

5.1.2 For consumable electrode remelted material, a heat is defined as all the ingot remelted from a primary heat. The heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. If the initial heat analysis does not meet the heat (ladle) analysis requirements of the specification, one sample from the product of each remelted ingot shall be analyzed and the analysis shall meet the heat (ladle) analysis requirements.

5.2 If the test samples taken for the heat analysis are lost, inadequate, or not representative of the heat, a product analysis of the semifinished or finished product may be used to establish the heat analysis.

5.2.1 If a product analysis is made to establish the heat analysis, the product analysis shall meet the specified limits for heat analysis and the product analysis tolerance described in Section 6 do not apply.

6. Product Analysis Requirements

6.1 For product analysis, the range of the specified chemical composition is normally greater (designated product analysis tolerances) than that applicable to heat analyses to take into account deviations associated with analytical reproducibility and the heterogeneity of the steel. If several determinations of any element in the heat are made, they may not vary both above and below the specified range.

6.2 Product analysis tolerances may not be used to determine conformance to the specified heat or cast analysis unless permitted by the individual material specification.

6.3 Product analysis tolerances, where available, are given in the individual material specification or in the general requirement specifications.

7. Unspecified Elements (Note 4)

7.1 Reporting analyses of unspecified elements is permitted.

NOTE 4 — All commercial metals contain small amounts of various elements in addition to those which are specified. It is neither practical nor necessary to specify limits for every unspecified element that might be present, despite the fact that the presence of many of these elements is often routinely determined by the producer.

7.2 Analysis limits shall be established for specific elements rather than groups of elements such as "all others," "rare earths," and "balance."

8. Reference Materials

8.1 For referee analyses, reference standards of a recognized standardizing agency shall be employed with preference given to NIST standard reference materials when applicable. (NIST does not produce reference standards suitable for all elements or all alloys.)

8.1.1 When standard reference materials for certain alloys are not available from NIST, reference materials may be produced by employing ASTM standard procedures and NIST standard reference materials to the extent that such procedures and reference standards are available. Several independent laboratories should be used for certification of these standards and their results statistically reviewed and merged.

8.1.2 Methods not published by ASTM such as a definitive analytical method may be used when the method is validated by analyzing certified reference materials along with the candidate reference material. Examples of definitive analytical methods include gravimetric, coulometry, titrimetric based on normality, and mass spectrometry.

8.2 Working reference materials may be used for routine analytical control.

9. Sampling

9.1 *Cast or Heat Analyses:*

9.1.1 Samples shall be taken insofar as possible, during the casting of a heat, at a time which, in the producer's judgment, best represents the composition of the cast.

9.1.2 In case the heat analysis samples or analyses are lost or inadequate, or when it is evident that the sample does not truly represent the heat, representative samples may be taken from the semifinished or finished product, in which case such samples may be analyzed to satisfy the specified requirements. The analysis shall meet the specified limits for heat analysis.

9.2 *Check, Product, or Verification Analyses:*

9.2.1 Unless otherwise specified, the latest revision of Practice E 59 shall be used as a guide for sampling.

10. Test Methods

10.1 This section lists some methods that have been found acceptable for chemical analysis of steels.

10.1.1 The following ASTM wet chemical methods have been found acceptable as referee test methods and as a base for standardizing instrumental analysis techniques:

Test Methods	General Description
E 30	antecedent to Methods E 350 through E 354
E 350	the basic wet chemical procedure for steels
E 352	wet chemical procedure for tool steels
E 353	wet chemical procedure for stainless steels
E 354	wet chemical procedure for high nickel steels
E 1019	determination of carbon, sulfur, nitrogen, oxygen, and hydrogen, in steel and in iron, nickel, and cobalt alloys

10.1.2 The following ASTM instrumental test methods, practices, and guides may be employed for chemical analysis of steels or may be useful as a guide in the calibration and standardization of instrumental equipment for routine analysis of steels:

Methods	General Description
E 50	apparatus, reagents, and safety
E 60	photometric and spectrophotometric work
E 212	spectrographic analysis of steels (rod-to-rod technique)
E 293	spectrophotometric analysis of acid-soluble aluminum
E 322	X-ray fluorescence for steels
E 327	spectrometric analysis of stainless steels
E 403	spectrometric analysis of steels
E 404	spectrographic determination of steels for boron (point-to-plane technique)
E 415	vacuum spectrometric analysis of steels
E 421	spectrographic determination of silicon and aluminum in high-purity iron
E 485	optical emission vacuum spectrometric analysis of blast furnace iron by the point-to-plane technique
E 572	X-ray emission spectrometric analysis of stainless steels
E 1019	determination of carbon, sulfur, nitrogen, oxygen, and hydrogen in steel and in iron, nickel, and cobalt alloys
E 1024	flame atomic absorption

Methods	General Description
E 1063	X-ray emission of spectrometric determination of cerium and lathanum in carbon and low-alloy steels
E 1086	optical emission vacuum spectrometric analysis of stainless steel by the point-to-plane excitation technique
E 1087	sampling
E 1097	direct current plasma spectroscopy
E 1184	graphite furnace atomic absorption
E 1282	selecting sampling practices and analysis methods
E 1329	verification and use of control charts

10.2 The following are some of the commonly accepted techniques employed for routine chemical analysis of steel. These routine analyses are the basis of the producers' quality control/assurance programs. Proprietary methods are permissible provided the results are equivalent to those obtained from standard methods when applicable.

10.2.1 Analysis of stainless steels using an X-ray fluorescence spectroscopy (XRF). See Table 1 for normal elements and ranges for stainless steels.

10.2.2 Analysis of stainless steels using spark emission spectroscopy (OES). See Table 2 for normal elements and ranges for stainless steel.

10.2.3 Analysis of solutions using an atomic absorption spectrophotometer.

10.2.4 Analysis of solutions using an inductively coupled plasma emission spectrometer.

10.2.5 Determination of carbon or sulfur, or both, by combustion (in oxygen) and measurement of CO_2, or SO_2, or both, by thermal conductivity or infrared detectors.

Element	Ranges %	Elements	Ranges %
C	0.002–5.0	S	0.0005–0.1

10.2.6 Determination of nitrogen and oxygen by fusion (in a helium atmosphere) and measurement of N_2 by thermal conductivity and oxygen by measurement of CO by infrared or thermal conductivity detectors.

Element	Ranges %
N_2	0.0005–0.3
O_2	0.008–0.02

10.2.7 Analysis of solutions using inductively coupled plasma emission spectroscopy (ICP) or direct plasma emission spectroscopy (DCP). Normal elements and ranges for stainless steels are as follows:

Element	Ranges %
B	0.0002–0.01
Ca	0.0002–0.01
Mg	0.0002–0.01
Ce	0.001–0.2
Zr	0.001–0.1
Ta	0.005–0.5
La	0.001–0.01

10.3 There are additional common techniques often used for chemical analysis of standards for instrument analysis such as: polarographic analysis, ion exchange separations, radioactivation, and mass spectrometry.

11. Significant Numbers

11.1 Laboratories shall report each element to the same number of significant numbers as used in the pertinent material specifications.

11.2 When a chemical determination yields a greater number of significant numbers than is specified for an element, the result shall be rounded in accordance with Section 12.

12. Rounding Procedure

12.1 To determine conformance with the specification requirements, an observed value or calculated value shall be rounded in accordance with Practice E 29 to the nearest unit in the right-hand place of values listed in the table of chemical requirements.

12.2 In the special case of rounding the number "5" when no additional numbers other than "0" follow the "5", rounding shall be done in the direction of the specification analysis limits if following Practice E 29 would cause rejection to material.

13. Report

13.1 The chemical analysis of a heat shall be reported only when specified by the user or the material specification.

NOTE 5 — Columbium, Cb, is also known as niobium, Nb.

13.2 Certification or identification to an ASTM material standard requires that the specific heat of steel meets the chemical requirements of the ASTM standard.

13.3 Any report that is legally binding on the manufacturer is acceptable as a certified test report.

13.3.1 Notarization of Certificates of Test is neither required nor prohibited.

14. Keywords

14.1 cast analysis; chemical analysis; heat analysis; product analysis; reference materials.

TABLE 1
NORMAL ELEMENTS AND RANGES FOR STAINLESS STEELS USING X-RAY FLUORESCENCE SPECTROSCOPY

Element	Ranges %	Element	Ranges %
MN	0.005–15.0	Cu	0.005–4.0
P	0.001–0.15	Cb	0.005–3.0
Si	0.005–5.0	V	0.005–2.0
Cr	0.01–26.0	Ti	0.005–2.5
Ni	0.01–36.0	Co	0.005–4.0
Al	0.002–5.5	Sn	0.002–0.20
Mo	0.005–8.0	W	0.005–3.0

TABLE 2
NORMAL ELEMENTS AND RANGES FOR STAINLESS STEELS USING SPARK EMISSION SPECTROSCOPY

Element	Ranges %	Element	Ranges %
C	0.004–5.0	V	0.005–2.0
S	0.0005–0.1	Ti	0.005–2.5
N_2	0.0020–0.3	Co	0.005–4.0
MN	0.005–15.0	Sn	0.001–0.20
P	0.001–1.5	W	0.005–3.0
Si	0.005–5.0	Pb	0.002–0.05
Cr	0.01–26.0	B	0.0005–0.05
Ni	0.01–36.0	Ca	0.0002–0.01
Al	0.001–5.5	Mg	0.001–0.01
Mo	0.005–8.0	Ce	0.001–0.2
Cu	0.005–4.0	Zr	0.001–0.1
Cb	0.005–3.0	Ta	0.005–0.5

SPECIFICATION FOR CARBON STEEL AND LOW-ALLOY STEEL PRESSURE VESSEL COMPONENT FORGINGS WITH MANDATORY TOUGHNESS REQUIREMENTS

SA-765/SA-765M

(Identical with ASTM Specification A 765/A 765M-94)

1. Scope

1.1 This specification covers heat-treated carbon steel and alloy steel forgings with mandatory toughness requirements. These forgings are intended for pressure vessels, feedwater heaters, and similar uses.

1.2 These forgings include tube sheets, covers, channel barrels, integral forged channels, rings, nozzles, flanges, and similar parts.

1.3 All grades are considered weldable under proper conditions.

1.4 The maximum thickness of forgings produced to this specification is limited only by the capacity of the selected grade to respond to any heat treatment specified and to meet the specified mechanical tests, including impact tests at the specified temperature.

1.5 The values stated in either inch-pound units or SI [metric] units are to be regarded separately as the standard; within the text and tables, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.6 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 388 Practice for Ultrasonic Examination of Heavy Steel Forgings

A 788 Specification for Steel Forgings, General Requirements

E 112 Test Methods for Determining the Average Grain Size

E 165 Practice for Liquid Penetrant Inspection Examination

2.2 *ASME Standards:*

Boiler and Pressure Vessel Code — Sections III, VIII, and IX

3. Ordering Information

3.1 Orders shall include the following information:

3.1.1 Applicable ordering information outlined, in Specification A 788,

3.1.2 Drawing showing area of significant loading, if necessary,

3.1.3 Impact test temperature requirement (see 6.1.1),

3.1.4 Forgings that are intended for ASME code usage, and

3.1.5 Drawings showing dimensions prior to heat treatment for properties and test location must be submitted for approval.

4. Heat Treatment for Mechanical Properties

4.1 Heat treatment shall consist of normalizing and tempering, double normalizing and tempering, or quenching and tempering at the manufacturer's option.

4.2 Forgings heat treated by the quenching and tempering method shall be marked in accordance with 9.3.

5. Chemical Requirements

5.1 *Heat Analysis* — The heat analysis obtained from sampling in accordance with Specification A 788 shall comply with Table 1.

5.2 *Product Analysis* — The purchaser may use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat.

6. Mechanical Requirements

6.1 *General Requirements* — The forgings shall conform to the tension test requirements of Table 2. The forgings shall also conform to the impact test requirements of Table 3. The largest obtainable round tension test specimen as specified in Test Methods and Definitions A 370 shall be used. Impact specimens shall be Charpy V-notch, Type A, as in Test Methods and Definitions A 370. The usage of subsize impact specimens must have prior purchaser approval.

6.1.1 When agreed upon between the purchaser and the producer and specified on the order, impact tests may be made at temperatures different from those shown in Table 3 provided the test temperature is at least as low as the intended service temperatures and the provided impact energy requirements of Table 3 are met. Such forgings shall be suitably marked in accordance with 9.2 to identify the test temperature.

6.2 *Test Location* — Test coupons shall be taken so that the longitudinal axis and mid-length of tension and impact test specimens shall be positioned in accordance with one of the following methods:

6.2.1 *Method I* — Forgings with 2 in. [50 mm] maximum thickness. The specimens shall have their longitudinal axis at the midthickness or the center of the cross section and with the midlength of the specimen at least 2 in. [50 mm] from any second surface.

6.2.2 *Method 2* — Grade I and Grade II forgings with thicknesses greater than 2 in. up to 4 in. [50 to 100 mm] inclusive, or Grade III and IV forgings with thicknesses greater than 2 in. up to 6 in. [50 to 150 mm] inclusive. The specimens shall have their longitudinal axis at least $\frac{1}{4}$ *T* of maximum heat-treated thickness from any surface and with the midlength of the specimen at least one *T* from any second surface. This is normally referred to as $\frac{1}{4}$ *T* by *T* when *T* is the maximum heat-treated thickness. A thermal buffer may be used to adhere to the above condition (6.3). Unless otherwise agreed upon, the following limitation for heat-treated thickness shall apply:

Grade	in. [mm], min	in. [mm], max
I	2[50]	4[100]
II	2[50]	4[100]
III	2[50]	6[150]
IV	2[50]	6[150]

6.2.3 *Method 3* — Forgings thicker than described in Method 2:

6.2.3.1 The longitudinal axis of the specimen shall not be nearer than $\frac{3}{4}$ in. [20 mm] to any heat-treated surface, and the midlength of the specimens shall be at least $1\frac{1}{2}$ in. [40 mm] from any second heat-treated surface.

6.2.3.2 When this method is employed for ASME Code usage (see 3.1.4), forgings are manufactured with a purchaser-approved drawing showing pre-heat-treated dimension and the location of mechanical test specimens. In those cases, specimens shall be positioned *t* by 2*t* where *t* is the distance from the area of significant loading to the nearest heat-treated surface, but not nearer the surface outlined in 6.2.3.1.

6.2.4 *Method 4* — Separate test forging when agreed upon between the purchaser and the supplier. Test coupons representing forgings from one heat and one heat treatment lot may be taken from a separately forged piece under the following conditions:

(a) The separate test forging shall be of the same heat of material and shall be subjected to substantially the same reduction and working as the production forging it represents.

(b) The separate test forging shall be heat treated in the same furnace charge and under the same conditions as the production forging.

(c) The separate test forging shall be of the same nominal thickness as the production forging.

(d) Test coupons for small forgings as described in Method 2 shall be taken so that specimens shall have their longitudinal axes at the region midway between midthickness and the surface and with the midlength of the specimens no nearer any heat-treated edge than a distance equal to the forging thickness except when the thickness-to-length ratio of the production forging does not permit, in which case a production forging shall be used as the test forging and the midlength of the specimens shall be at the midlength of the test forging.

(e) Test coupons for larger forgings shall be taken in accordance with Method 3.

This method shall be limited to forgings with a rough machined weight of not more than 1000 lb [455 kg].

6.3 *Metal Buffers* — The required distances from treated surfaces may be obtained with metal buffers instead of integral extensions. Buffer material may be carbon or low-alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at ½ in. [13 mm] minimum from the buffered surface of the forging. Buffers shall be removed and the welded areas subjected to magnetic particle test to assure freedom from cracks unless the welded areas are completely removed by subsequent machining.

6.4 Samples shall be removed from forgings after heat treatments. This sample material shall be subjected to a simulated post-weld heat treatment if Supplementary Requirement S6 is specified.

6.5 *Test Orientation* — For upset disk forging, the longitudinal axis of all test specimens shall be oriented in the tangential direction. For all other forgings, the longitudinal axis of the specimens may be oriented in the direction of maximum working of the forging.

6.6 *Number of Tests:*

6.6.1 *Forgings Under 500 lb* [*230 kg*] *As Treated* — For duplicate forgings weighing less than 500 lb as treated, one tension test and one impact test (three specimens) shall be made to represent each heat in each heat-treatment charge. When heat treatment is performed in continuous-type furnaces with suitable temperature control and equipped with recording pyrometers so that complete heat-treatment records are available, a heat-treatment charge shall be considered as any continuous run not exceeding an 8-h duration.

6.6.2 *Forging Weighing 500 to 10 000 lb* [*230 to 4500 kg*] *As-Heat Treated* — One tension and one impact test (three specimens) shall be made for each forging.

6.6.3 Each forging weighing over 10 000 lb [4500 kg] shall require two tension tests and two impact tests (three specimens). When the length (excluding prolongs) is equal to or less than 1½ times the diameter, the tests may be taken from one end of the forging with a tension test and one set of impact tests at each of two locations oriented 180° apart. When the length (excluding prolongs) is greater than 1½ times the diameter, one tension test and one set of impact tests must be taken from each location from opposite ends of the forging and the locations on each end should be oriented 180° apart from each other.

7. Repair Welding

7.1 Repair welding shall be permitted but only at the option of the purchaser and shall be performed in accordance with all the requirements of Part UF of Section VIII (Div. 1) of the ASME Boiler and Pressure Vessel Code.

8. General Requirements

8.1 In addition to the ordering information required by Specification A 788, the purchaser shall include with the inquiry and order, a detailed drawing, sketch, or written description of the forging and the method of selecting test location (see 6.2). When appropriate, the areas of significant loading in the forging shall be designated.

8.2 Material supplied to this specification shall conform to the requirements of Specification A 788, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

8.3 If the requirements of this specification are in conflict with the requirements of Specification A 788, the requirements of this specification shall prevail.

9. Product Marking

9.1 Each forging shall be legibly marked either by stenciling or stamping by the manufacturer with the appropriate grade and heat number.

9.2 The test temperature shall also be shown if it is other than the minimum temperature shown in Table 3. A prefix "O" to the test temperature shall indicate a temperature lower than 0°F [°C]. For example, A-765-I-10 [A-765-I-10] indicates a temperature of plus 10°F [10°C]; whereas A-765-I-0125 [A-765-I-0125] indicates a temperature of minus 125°F [25°C].

9.3 Forgings that have been liquid quenched in accordance with 5.2.2 shall be marked with a "Q" following the grade identification, for example, A-XXX-IIQ-040.

9.4 When stamps are used, the type of stamps to be used shall be round-nosed or "interrupted dot" die stamps having a minimum radius of $\frac{1}{32}$ in. [0.8 mm].

10. Keywords

10.1 alloy steel forgings; carbon steel forgings; heat-treated; impact tested; pressure vessel; weldable.

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %			
	Grade I	Grade II	Grade III	Grade IV
Carbon, max	0.30	0.30	0.20	0.20
Manganese	0.60 to 1.05	0.60 to 1.35	0.90 max	1.00–1.60
Phosphorus, max	0.020	0.020	0.020	0.020
Sulfur, max	0.020	0.020	0.020	0.020
Silicon	0.15 to 0.35	0.15 to 0.35	0.15 to 0.35	0.15–0.50
Nickel[A]	0.50 max	0.50 max	3.3 to 3.8	0.50 max
Vanadium, max	0.05	0.05	0.05	0.06
Aluminum, max	0.05	0.05	0.05	0.05
Chromium,[A] max	0.40	0.40	0.20	0.40
Molybdenum,[A] max	0.25	0.25	0.06	0.25
Copper, max	0.35	0.35	0.35	0.35

[A] Intentional additions of Cr, Mo, and Ni up to the specified maximum are permitted to be made to Grades I, II, and IV by the manufacturer.

TABLE 2
TENSILE REQUIREMENTS

	Grade I	Grade II	Grade III	Grade IV
Tensile strength, ksi [MPa]	60 to 85 [415 to 585]	70 to 95 [485 to 655]	70 to 95 [485 to 655]	80–105 [550–725]
Yield strength,[A] min, ksi [MPa]	30 [205]	36 [250]	37.5 [260]	50 [345]
Elongation in 2 in. [50 mm], min, %	25	22	22	22
Reduction of area, min, %	38	30	35	30

[A] 0.2% offset or 0.5% total extension underload method.

TABLE 3
CHARPY V-NOTCH IMPACT REQUIREMENTS

	Grade I	Grade II	Grade III	Grade IV
Minimum average value of set of three specimens, ft-lbf (J)	13 [18]	15 [20]	15 [20]	28 [35][A]
Minimum value of one specimen, ft-lbf (J)	10 [14]	12 [16]	12 [16]	20 [27][A]
Test temperature of,[B] °F [°C]	−20 [−30]	−50 [−45]	−150 [−100]	−20 [−30]

[A] Mandatory conformance to the values listed is a matter of agreement between the purchaser and the manufacturer. The energy values above are shown for information as to guarantees that are generally available.
[B] Actual test temperature should be established at time of order. If no temperature is specified, tests will be made at test temperatures shown in this table.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the order. Details of these supplementary requirements shall have been previously negotiated and mutually agreed to between the forging manufacturer and the purchaser.

S1. Product Analysis

S1.1 The manufacturer shall use the product analysis provision of Specification A 788 to obtain a product analysis from a forging representing each heat or multiple heat.

S2. Grain Size

S2.1 The forgings, subsequent to the final heat treatment, shall have prior austenitic grain size of 5 or finer as determined by the McQuaid-Ehn Test (Methods E 112).

S3. Impact Transition Curve

S3.1 Sufficient impact tests shall be made from the forging test material to establish a temperature versus absorbed-energy curve. The test temperature range shall be wide enough to establish the upper and the lower shelf foot-pound-force (or joules) energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

S4. Magnetic Particle Examination

S4.1 All accessible surfaces of the finished forging shall be examined by a magnetic particle method. This method shall be in accordance with Test Method A 275/A 275M.

S4.2 Acceptance criteria shall be specified.

S5. Liquid Penetrant Examination

S5.1 All surfaces shall be examined by a liquid penetrant method. The method shall be in accordance with Practice E 165.

S5.2 Acceptance criteria shall be specified.

S6. Simulated Post-Weld Heat Treatment of Mechanical Test Samples

S6.1 All test coupons shall be subjected to single or multiple heat treatments at subcritical temperatures prior to testing. Such treatments are intended to simulate post-weld or other treatments to which the forgings will be subjected during subsequent fabrication. The purchaser shall furnish the manufacturer with details of the desired heat treatment for the test coupons, including temperatures, times, and cooling rates.

S7. Vacuum Treatment

S7.1 The molten steel shall be vacuum treated prior to or during the pouring of the melt. Unless otherwise agreed upon with the purchaser, it is the responsibility of the manufacturer to select suitable process procedures subject to the following requirements:

S7.1.1 When the vacuum stream degassing is used, the vacuum system must be of sufficient capacity to effect a blank-off pressure low enough (usually less than 1000 μm Hg) to break up the normal tight, rope-like stream of molten metal into a wide-angled conical stream of relatively small droplets. The capacity of the system must also be sufficiently high to reduce the initial surge pressure at the start of the pour to a low level within 2 min.

S7.1.2 When the vacuum-lift process is utilized, the molten metal shall be drawn into the evacuated vessel a sufficient number of times to assure thorough mixing and degassing of the entire volume of metal. The evacuation system shall be capable of reducing the pressure surges which occur each time a new portion of steel is admitted to the vessel to increasingly lower levels until a blank-off pressure of less than 1000 μm Hg is achieved, thus signifying the end of the degassing treatment.

S8. Ultrasonic Examination

S8.1 Forgings shall be ultrasonically examined in accordance with the procedures of Practice A 388/A 388M.

S8.2 Acceptance criteria shall be specified.

S9. Special Tension Specimens for Hubbed Flanges and Tube Sheets

S9.1 For forged-hub tube sheets and flanges to be used in ASME Code stamped vessels, a tension specimen shall be taken as close to the hub as possible. The longitudinal axis of the specimen shall be parallel to the length of the hub (see Fig. UW-13.3, ASME Code Section VIII/I).

SPECIFICATION FOR THROUGH-THICKNESS TENSION TESTING OF STEEL PLATES FOR SPECIAL APPLICATIONS

SA-770/SA-770M

(Identical with ASTM Specification A 770/A 770M-86.)

1. Scope

1.1 This specification covers the procedures and acceptance standards for the determination of reduction of area using a tension test specimen whose axis is perpendicular to the rolled surfaces of steel plates 1 in. [25 mm] and greater in thickness. The principal purpose of the testing is to provide a measure of the resistance of a steel plate to lamellar tearing. (See Appendix X1.)

1.2 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 This specification is expressed in both inch-pound and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

2. Applicable Document

2.1 *ASTM Standard:*

A 370 Methods and Definitions for Mechanical Testing of Steel Products

3. Ordering Information

3.1 The inquiry and order shall include the following, if required:

3.1.1 Supplementary requirements that are available to meet end use requirements (see S1 through S5).

3.1.2 Special requirements agreed upon between the manufacturer and the purchaser.

4. Tension Tests

4.1 *Number of Tests:*

4.1.1 Two tests shall be required from each plate-as-rolled, except for plates subjected to heat treatment by quenching and tempering. Two tests shall be required from each quenched-and-tempered plate. The tests shall be representative of the plate in its final condition.

4.1.2 When plates are furnished by the manufacturer in an unheat-treated condition and qualified by heat-treated specimens (including normalized, normalized and tempered, and quenched and tempered), two tests shall be required from each plate-as-rolled.

NOTE — The term "plate-as-rolled" refers to the unit plate rolled from a slab or directly from an ingot. It does not refer to the condition of the plate.

4.2 *Location of Test Coupons* — Take one test coupon at each end of each plate as defined in 4.1. Take the test coupons from the center of the plate width.

4.3 *Orientation of Test Specimens* — The longitudinal axis of the reduced section of the test specimens shall be perpendicular to the rolled surface of the plate.

4.4 *Preparation of Test Specimens:*

4.4.1 *Welded Prolongations* — When required, join welded prolongations to the surface(s) of the plate being tested. The joining method used shall be one which results in a minimal heat-affected zone in the portion of the plate to be tested. Shielded metal arc, friction, stud, or electron-beam welding methods have proven to be suitable.

4.4.2 *Types of Test Specimens:*

4.4.2.1 Three types of standard round tension test specimens are shown in Fig. 1 and Table 1. For Types 1 and 2 specimens, locate the center of the length of the reduced section at the approximate mid-point of the plate thickness. For Type 3 specimens, locate the weld fusion line of one plate surface within $\frac{1}{4}$ in. [6 mm] of one end of the reduced section.

4.4.2.2 For plates from 1 in. [25 mm] to $1\frac{1}{4}$ in. [32 mm] inclusive in thickness, use either the 0.350 in. [8.75 mm] Type 1 specimen or the 0.500 in. [12.5 mm] Type 2 specimen.

4.4.2.3 For plates over $1\frac{1}{4}$ in. to 2 in. [50 mm] inclusive in thickness, use the 0.500 in. [12.5 mm] Type 2 specimen.

4.4.2.4 For plates greater than 2 in. [50 mm] in thickness, use the Type 3 specimen.

4.4.3 *Alternative Test Specimens* — The alternative test specimens in Fig. 2 and Table 2 may be used in place of the standard specimens in Fig. 1 and Table 1, subject to agreement between the manufacturer and the purchaser.

4.4.3.1 For plates over 2 in. [50 mm] in thickness, Type A or Type B specimens may be used. The Type A specimen provides a reduced section length greater than the plate thickness. The Type B specimen provides a reduced section length of $2\frac{1}{4}$ in. [57 mm] with its center at the mid-thickness of the plate. Over a minimum plate thickness determined by the specimen end configuration, no welded prolongations may be needed for the Type B specimen. For plates over $4\frac{1}{4}$ in. [108 mm] in thickness, the standard round tension test specimen Type C may be used. For plates over 6 in. [150 mm] in thickness, a series of two or more Type A or Type C specimens with reduced sections of 4 in. [100 mm] or less may be used to cover the full thickness of the plate. The number of tests required will depend upon the thickness of the plate being tested and the reduced section length selected.

4.4.3.2 For plates over 1 in. [25 mm] in thickness, a series of button-head specimens shown in Fig. 2 and Table 2 may be used. The test specimen type to be used, Type D, Type E, or Type F, is determined by the nominal plate thickness as described in Table 2. A series of two or more Type F specimens may be used to cover the full thickness of the plate. The length of the reduced section (*A*), as shown in Fig. 2 and specified in Table 2, is the length of the reduced section excluding the machined radius (*R*). Within the plate thickness dimension specified for each test specimen type, either the button-head thickness, the reduced section length, or the machined radius may be varied. In all cases, the minimum length of the reduced section must be as specified in Table 2 to maintain a minimum length to diameter ratio (see Appendix X2.2).

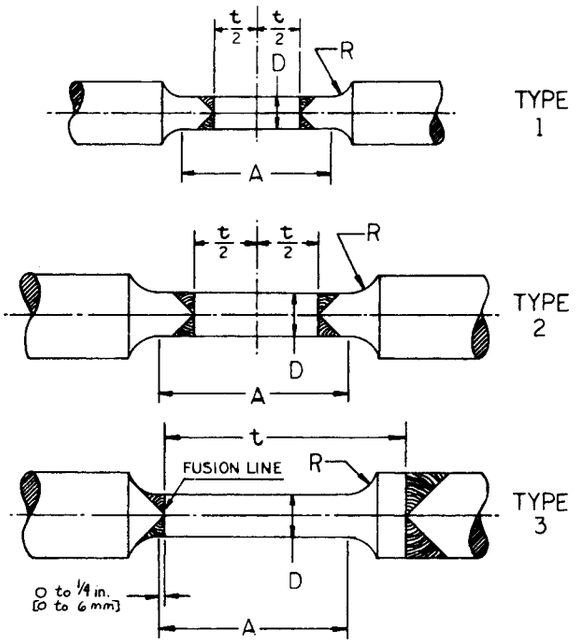
5. Acceptance Standards

5.1 Each tension test shall have a minimum reduction of area no less than 20%. If the reduction of area of both tests is less than 20%, no retest shall be permitted. If the reduction of area of one of the two tests from a plate is less than 20%, one retest of two additional specimens taken from a location adjacent to the specimen that failed may be made, and both of these additional specimens shall have a reduction of area of 20% or more.

5.2 Failures occurring in the prolongations, the weld, or in the fusion line shall be considered as a "no-test," and an additional specimen shall be tested.

6. Marking

6.1 Plates accepted in accordance with this specification shall be identified by stamping or stenciling ZT adjacent to the marking required by the applicable product specification.



NOTE—For Type 3 only one welded prolongation may be needed, depending upon plate thickness.

FIG. 1 STANDARD ROUND TENSION TEST SPECIMENS

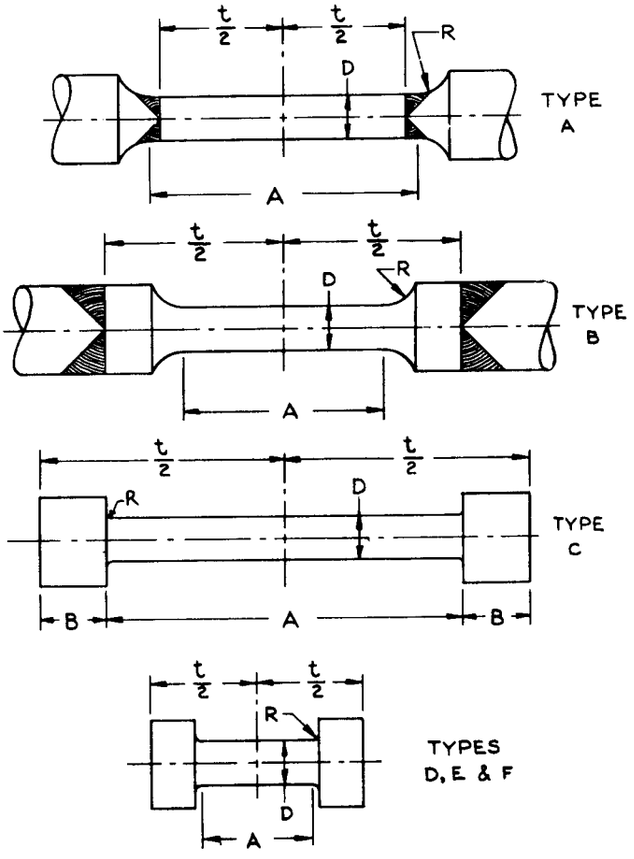


FIG. 2 ALTERNATIVE TENSION TEST SPECIMENS

TABLE 1
SCHEDULE OF STANDARD TEST SPECIMENS, INCHES [MILLIMETRES][A]

	Specimen Type		
	1	2	3
Plate thickness(*t*)	$1 \le t \le 1\frac{1}{4}$	$1 < t \le 2$	$2 < t$
Diameter(*D*)	0.350 [8.75]	0.500 [12.5]	0.500 [12.5]
Radius, minimum(*R*)	$\frac{1}{4}$ [6]	$\frac{3}{8}$ [10]	$\frac{3}{8}$ [10]
Length of reduced section(*A*)	$1\frac{3}{4}$ [45]	$2\frac{1}{4}$ [60]	$2\frac{1}{4}$ [60]

[A] See Methods and Definitions A 370 (Fig. 5 for further details and Fig. 6 for various types of ends).

TABLE 2
SCHEDULE OF ALTERNATIVE TEST SPECIMENS, INCHES [MILLIMETRES]

	Specimen Type					
	A[A]	B[A]	C[B]	D	E	F
Plate thickness(t)	2 < t (50 < t)	2 < t (50 < t)	4¼ < t (108 < t)	1 ≤ t ≤ 1¾ (25 ≤ t ≤ 45)	1¾ < t ≤ 2½ (45 ≤ t ≤ 64)	2½ < t (64 < t)
Diameter(D)	0.500 (12.5)	0.500 (12.5)	0.500 (12.5)	0.250 (6.25)[C] ± 0.005 (0.10)	0.350 (8.75)[C] ± 0.007 (0.18)	0.500 (12.5)[C] ± 10.010 (0.25)
Radius, min(R)	⅜ (10)	⅜ (10)	1/16 (10)	optional	optional	optional
Length of reduced section min(A)	t + ¼ min (t + 6)	2¼ (60)	t − 1½ (t − 38)	0.625 (16)	0.875 (22)	1.250 (32)

[A] See Methods and Definitions A 370 (Fig. 5 for further details and Fig. 6 for various types of ends).
[B] See Methods and Definitions A 370 (Fig. 6, specimen 3 for further details).
[C] The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1% larger in diameter than the center (controlling dimension).

SUPPLEMENTARY REQUIREMENTS

These requirements apply only when specified by the purchaser.

S1. Tensile Strength Requirements

S1.1 Tensile strength shall conform to a minimum value which is subject to agreement between the manufacturer and purchaser.

S2. Yield Strength Requirements

S2.1 Yield strength, for plates 2 in. [50 mm] and over in thickness, shall conform to a minimum value which is subject to agreement between the manufacturer and purchaser.

S3. Reduction of Area Requirements

S3.1 A minimum reduction of area limit higher than that in 5.1 may be specified subject to agreement between the manufacturer and purchaser.

S4. Number of Tests

S4.1 A greater number of tests than indicated in 4.1 may be specified subject to agreement between the manufacturer and purchaser.

S5. Location of Test Coupons

S5.1 Test coupons from locations in addition to those specified in 4.2 may be specified subject to agreement between the manufacturer and purchaser.

APPENDICES

(Nonmandatory Information)

X1. LAMELLAR TEARING ADJACENT TO WELDS

X1.1 Introduction

X1.1.1 Lamellar tearing is a particular type of cracking that occurs under the weld of a steel plate weldment. It is generally caused by strain induced in the thickness direction resulting from shrinkage of the weld deposit and by the restraint imposed by the components that comprise the weldment. High restraint increases the possibility of lamellar tearing. However, lamellar tearing is not solely confined to highly restrained weldments. Lamellar tearing may also result from loads on the plate surface.

X1.2 Characteristics of Lamellar Tearing

X1.2.1 Lamellar tearing normally occurs in susceptible material underneath the weld, in a direction generally parallel to the plate surface and often slightly outside the heat-affected zone. Lamellar tearing generally has a step-like appearance consisting of “terraces” (cracks running parallel to the plate surface) and “walls” (cracks which connect the individual terraces). The tearing may remain completely subsurface or appear at plate edges or at weld toes.

X1.3 Inclusions

X1.3.1 The step-like cracking characteristic of lamellar tearing is usually considered to result from small elongated nonmetallic inclusions that are normally present in the steel. Strains in the through-thickness direction can cause individual inclusions to fractures or decohere from the surrounding steel matrix, thus initiating a void. Further strain can cause the remaining metallic ligaments to shear or rupture, resulting in the step-like fracture appearance.

X1.3.2 A high or concentrated inclusion content in the steel produces planer regions of poor ductility parallel to the steel surface. On the other hand, a reduction in the magnitude and concentration of these inclusions to a low level tends to preclude any easy fracture path along the low ductility inclusions and the steel exhibits improved ductility in a through-thickness direction.

X1.3.3 The extent of nonmetallic inclusions depends on the type of steel. In silicon semikilled or fully killed steels, these inclusions are primarily oxides (present as silicates) and sulfides (present as manganese sulfides). For aluminum-silicon killed steels, these inclusions are primarily sulfides (manganese sulfides). To improve the through-thickness ductility and thus the resistance of the steel to lamellar tearing, it is necessary to reduce the level of the nonmetallic inclusions. To provide a high resistance to lamellar tearing may require the use of special steel-making processes that can reduce the oxygen and sulfur contents in the steel to very low levels.

X1.4 Steel Manufacturing Processes

X1.4.1 Special steel-making processes are available for improving the through-thickness ductility. The more common processes, used singly or in combination, are: (*1*) low sulfur practices; (*2*) inclusion shape control; (*3*) electroslag or vacuum are remelting; and (*4*) vacuum degassing. The steel-making processes are not all intended for the same purpose, but will improve the through-thickness ductility to various degrees depending on the process used.

X1.5 Through-Thickness Ductility Requirements

X1.5.1 Susceptibility to lamellar tearing depends on many factors (for example, restraint, welding conditions, etc.) and, consequently a specific through-thickness ductility requirement does not provide a guarantee against lamellar tearing. The most widely accepted method of measuring the material ductility factor of susceptibility to lamellar tearing is the reduction of area of a round tension test specimen oriented perpendicular to the rolled surface of a plate.

X2. TESTING PARAMETERS AFFECTING REDUCTION OF AREA VALUES

X2.1 Variability of Through-Thickness Properties

X2.1.1 Through-thickness tension test results, and in particular the reduction of area determination as provided for in this specification, are subject to substantially greater scatter than would normally be expected from standard tension tests of a plate in the longitudinal

or transverse direction. This scatter of test results is due in part to the inherent variability of the distribution of the nonmetallic inclusions discussed in X1.3. For example, those nonmetallic inclusions that form during the solidification phase of the steelmaking process tend to occur with a higher frequency in the area of final solidification.

X2.1.2 Test specimen design may also have an effect on the test results. Some of these factors are discussed in X2.2. Operator technique will also be a factor in increasing scatter, particularly in the measurement of the final diameter of the test specimen. Because of the effect of inclusions on the fracture process, the appearance of the final fracture may be quite different than the classical cup-cone fractures common to longitudinal and transverse tension testing. For those materials with approximately 20% reduction of area, the final diameter measurement may require a substantial amount of judgment on the part of the test operator.

X2.1.3 In view of the potential variability of the through-thickness reduction of area test results, it is recognized that two tests per plate are not sufficient to fully characterize the through-thickness ductility of that plate. The number of tests and test positions have not been established that would provide a good estimate of both the mean and the variability of through-thickness tensile reduction of values of a plate. Therefore, an average value requirement is not included in this specification. The intent of this specification is to qualify a plate according to the described testing procedures using only a minimum value requirement. The potential variability of the test results also increases the possibility that subsequent testing of a steel plate qualified according to this specification may produce results that do not meet the specified acceptance standard.

X2.2 Effects of Test Specimen Design

X2.2.1 Two main factors considered in the selection of test specimen geometry were the diameter and the slenderness ratio. It is generally accepted that there is a diameter effect on reduction-of-area values such that a smaller diameter specimen generally yields a higher average reduction in area value. It is also accepted that smaller diameter test specimens will tend to give greater variability to the resulting reduction in area values. Because these relationships between the test specimen diameter and the average and variability of the test result have not been satisfactorily quantified at this time, the same minimum requirement has been applied to all test specimen diameters.

X2.2.2 The slenderness ratio (reduced section length/reduced section diameter) is known to affect the reduction in area values when below a minimum value. This minimum value may be from 1.5 to 2.5, depending on the material. Below this minimum value, the reduction at the failure point in the reduced section is restrained by the larger cross section away from the reduced section. A minimum slenderness ratio of 2 was selected for the standard Type 2 specimen to allow a 0.500 in. [12.5 mm] diameter specimen to be used on a 1 in. [25 mm] plate. A minimum slenderness ratio of 2.5 was selected for the collar-button specimens (Types D, E, and F) to ensure that this effect is minimized for these test specimens.

SPECIFICATION FOR CASTINGS, STEEL AND ALLOY, COMMON REQUIREMENTS, FOR GENERAL INDUSTRIAL USE

SA-781/SA-781M

(Identical with ASTM A 781/A 781M-94a.) 98

1. Scope

98 **1.1** This specification covers a group of requirements that are mandatory requirements of the following steel casting specifications issued by the American Society for Testing and Materials. If the product specification specifies different requirements, the product specification shall prevail.

ASTM Designation	Title of Specification
A 27/A 27M	Steel Castings, Carbon, for General Application
A 128/A 128M	Steel Castings, Austenitic Manganese
A 148/A 148M	Steel Castings, High-Strength, for Structural Purposes
A 297/A 297M	Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat-Resistant for General Application
A 447/A 447M	Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service
A 486/A 486M	Steel Castings, for Highway Bridges
A 494/A 494M	Castings, Nickel and Nickel Alloy
A 560/A 560M	Castings, Chromium-Nickel Alloy
A 743/A 743M	Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application
A 744/A 744M	Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
A 747/A 747M	Steel Castings, Stainless, Precipitation Hardening
A 890/A 890M	Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application
A 915/A 915M	Steel Castings, Carbon and Alloy Chemical

1.2 This specification also covers a group of supplementary requirements that may be applied to the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 The requirements of the individual material specification, and this general specification shall prevail in the sequence named.

1.4 The values stated in either inch–pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch–pound units are applicable for material ordered to Specification A 781 and SI units for material ordered to Specification A 781M.

2. Referenced Documents

2.1 *ASTM Standards:* 98

A 27/A 27M Specification for Steel Castings, Carbon, for General Application

A 128/A 128M Specification for Steel Castings, Austenitic Manganese

A 148/A 148M Specification for Steel Castings, High Strength, for Structural Purposes

A 297/A 297M Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 447/A 447M Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service
A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
A 494/A 494M Specification for Castings, Nickel and Nickel Alloy
A 560/A 560M Specification for Castings, Chromium-Nickel Alloy
A 609/A 609M Practice for Castings, Carbon, Low-Alloy and Martensitic Stainless Steel, Ultrasonic Examination Thereof
A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, and Nickel-Base Corrosion Resistant, for General Application
A 744/A 744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
A 747/A 747M Specification for Steel Castings, Stainless, Precipitation Hardening
A 751 Test Methods, Practices, and Definitions for Chemical Analysis of Steel Products
A 800/A 800M Practice for Steel Casting, Austenitic Alloy, Estimating Ferrite Content Thereof
A 802/A 802M Practice for Steel Castings, Textures and Discontinuities, Evaluation and Specifying, by Visual Examination
A 890 Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application
A 915/A 915M Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application
A 919 Terminology Relating to Heat Treatment of Metals
E 94 Guide for Radiographic Testing
E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
E 165 Practice for Liquid Penetrant Method
E 186 Reference Radiographs for Heavy-Walled (2 to 4½ in. (51 to 114 mm)) Steel Castings
E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to-305 mm)) Steel Castings
E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness
E 709 Practice for Magnetic Particle Examination

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Test Methods and Definitions A 370, Test Methods, Practices, and Terminology A 751, and Terminology A 919 are applicable to this specification and those listed in 1.1. **98**

4. Materials and Manufacture

4.1 *Melting Process* — The steel shall be made by open-hearth or electric furnace process with or without separate refining such as argon-oxygen-decarburization (AOD) unless otherwise specified in the individual specification.

5. Chemical Composition

5.1 *Chemical Analysis* — Chemical analysis of materials covered by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

5.2 *Heat Analysis* — An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified in the individual specification for the grade being poured. The analysis shall be made from a test sample preferably taken during the pouring of the heat. When drillings are used, they shall be taken not less than ¼ in. [6.4 mm] beneath the surface. The chemical composition thus determined shall conform to the requirements in the individual specification for the grade being poured.

5.3 *Product Analysis* — A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis of carbon and alloy steel shall be taken no closer than ¼ in. to a cast surface, except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved, or shall be subject to rejection by the purchaser, except that the chemical composition determined for carbon and low alloy steel castings may vary from the specified limits by the amounts shown in Table 1. The product analysis tolerances of Table 1 are not applicable as acceptance criteria for heat

analysis by the casting manufacturer. When comparing product and heat analysis for other than carbon and low alloy steels, the reproducibility Data R_2, in Test Methods E 353 or E 354, as applicable, shall be taken into consideration.

5.4 *Unspecified Elements* — When chemical analysis for elements not specified for the grade ordered is desired, Supplementary Requirement S13 may be specified.

5.5 The substitution of a grade or composition different from that specified by the purchaser is prohibited.

6. Tensile Requirements

6.1 The individual product specifications vary as to whether tension tests are required; for this reason, and to determine specific test requirements, the individual product specification should be reviewed.

6.2 Unless otherwise specified by the purchaser, when mechanical properties are required by the product specification, test coupons may be cast integrally with the castings, or as separate blocks, in accordance with Figs. 1, 2, or 3 except when Supplementary Requirement S15 is specified. The test coupon in Fig. 3 shall be employed only for austenitic alloy castings with cross sections less than $2\frac{1}{2}$ in.

7. Workmanship, Finish, and Appearance

7.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser before manufacture is started. If the pattern is supplied by the purchaser, the dimensions of the casting shall be as predicted by the pattern.

8. Quality

8.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

8.2 When additional inspection is desired, Supplementary Requirements S1, S2, S3, S4, or S5 may be specified.

9. Repair

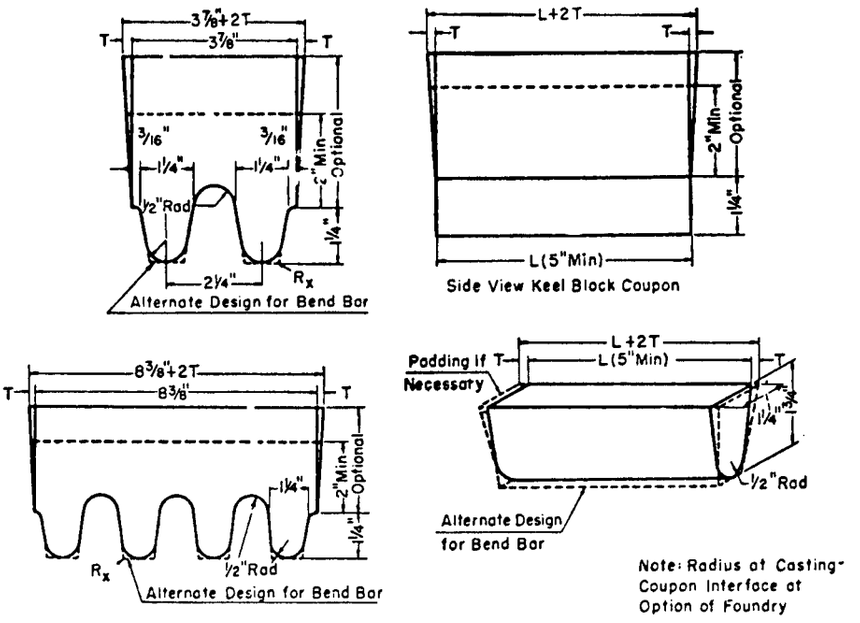
9.1 Repair by welding shall be in accordance with the requirements of the individual specification using procedures and welders qualified in accordance with Practice A 488/A 488M.

10. Inspection

10.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections, with the exception of product analysis (5.3), shall be made at the place of manufacture unless otherwise agreed.

11. Rejection

11.1 Subsequent to acceptance at the manufacturer's works, material which is found to be unacceptable as determined by requirements specified in the order may be rejected by the purchaser. The manufacturer should be notified of such rejection. If the manufacturer is dissatisfied with the results of any tests performed by the purchaser, he may make claim for a hearing.



Metric Equivalents

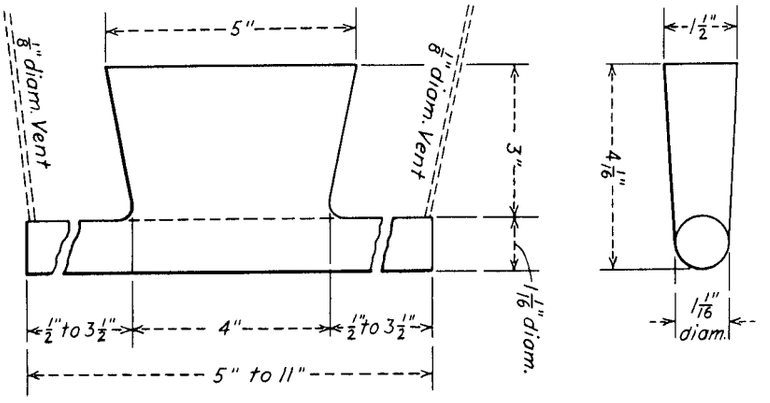
in.	3/16	½	1¼	1¾	2	2¼	3⅞	5	8⅜
[mm]	[4.8]	[13]	[32]	[45]	[51]	[57]	[98]	[127]	[213]

	Leg Design [125 mm]		Riser Design
1.	*L* (length)	A 5 in. [125 mm] minimun length will be used. This length may be increased at the option of the foundry to accommodate additional test bars (see Note 1).	1. *L* (length) The length of the riser at the base will be the same as the top length of the leg. The length of the riser at the top therefore depends on the amount of taper added to the riser.
2.	End Taper	Use of and size of end taper is at the option of the foundry.	2. Width The width of the riser at the base of a multiple-leg coupon shall be $n(2\frac{1}{4})$ [57 mm] − ⅝ [16 mm] where n equals the number of legs attached to the coupon. The width of the riser at the top is therefore dependent on the amount of taper added to the riser.
3.	Height	1¼ in. [32 mm]	
4.	Width (at top)	1¼ [32 mm] (see Note 1).	
5.	Radius (at bottom)	½ in. [13 mm], max	
6.	Spacing between legs	A ½-in. [13-mm] radius will be used between the legs.	
7.	Location of test bars	The tensile, bend, and impact bars will be taken the leg (see Note 2).	
8.	Number of legs	The number of legs attached to the coupon is at the option of the foundry providing they are equi-spaced according to Item 6.	3. *T* (riser taper) Use of and size is at the option of the foundry Height The minimum height of the riser shall be 2 in. [51 mm]. The maximum height is at the option of the foundry for the following reasons: (*a*) many risers are cast open. (*b*) different compositions may require variation in risering for soundness. (*c*) different pouring temperatures may require variation in risering for soundness.
9.	R_s	Radius from 0 to approximately 1/16 in. [2 mm].	

NOTE 1—*Test Coupons for Large and Heavy Steel Castings:* The test coupons in Fig. 1 are to be used for large and heavy steel castings. However, at the option of the foundry the cross-sectional area and length of the standard coupon may be increased as desired.

NOTE 2—*Bend Bar:* If a bend bar is required, an alternate design (as shown by dotted lines in Fig. 1) is indicated.

FIG. 1 TEST COUPONS FOR CASTINGS WITH DETAILS OF DESIGN

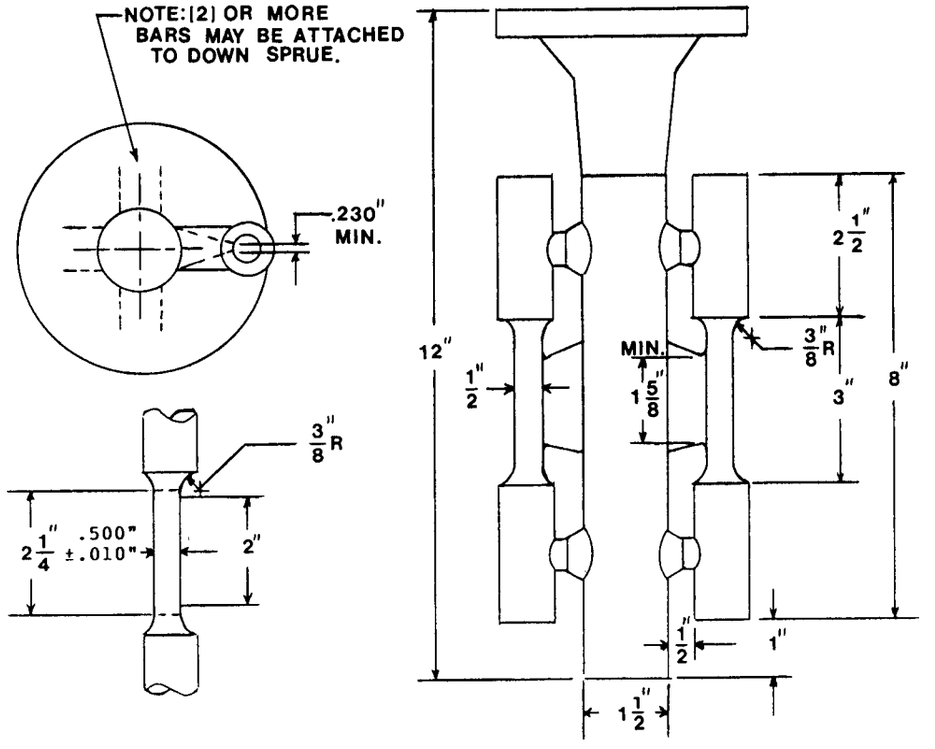


Metric Equivalents

in.	[mm]	in.	[mm]
1/8	[3.2]	3 1/2	[88.9]
1/2	[12.7]	4	[101.6]
1 1/16	[27.0]	4 1/16	[103.2]
1 1/2	[38.1]	5	[127.0]
3	[76.2]	11	[279.4]

NOTE—Pour through head; cover molten head with powdered charcoal, coke dust, etc., immediately after pouring, in order to keep head fluid as long as possible.

FIG. 2 TEST BLOCK FOR TENSION TEST SPECIMEN



NOTE—Coupons produced in this manner are suitable for austenitic alloys only. The mold may be preheated for pouring to produce a sound coupon.

FIG. 3 CAST-TO-SHAPE TEST COUPON FOR TENSION SPECIMEN

TABLE 1
PRODUCT ANALYSIS TOLERANCES

Element	Range, %[A]	Tolerances[B,C] Over Maximum or Under Minimum Limit, %
C	up to 0.65	0.03 × % C_L + 0.02
	above 0.65	0.04
Mn	up to 1	0.08 × % Mn_L + 0.01
	above 1	0.09
Si	up to 0.60	0.22 × % Si_L − 0.01
	above 0.60	0.15
P	all	0.13 × % P_L + 0.005
S	all	0.36 × % S_L + 0.001
Ni	up to 2	0.10 × % Ni_L + 0.03
	above 2	0.25
Cr	up to 2	0.07 × % Cr_L + 0.04
	above 2	0.18
Mo	up to 0.6	0.04 × % Mo_L + 0.03
	above 0.6	0.06
V	up to 0.25	0.23 × % V_L + 0.004
	above 0.25	0.06
W	up to 0.10	0.08 × % W_L + 0.02
	above 0.10	0.02
Cu	up to 0.15	0.18 × % Cu_L + 0.02
	above 0.15	0.05
Al	up to 0.10	0.08 × % Al_L + 0.02
	above 0.10	0.03

[A] The range denotes the composition limits up to which tolerances are computed by the equation, and above which the tolerances are given by a constant.

[B] The subscript $_L$ for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit (if applicable), respectively. Examples of computing tolerances are presented in footnote *C*.

[C] To illustrate the computation of the tolerance, consider the manganese maximum of 0.70 for an 0.30 carbon grade 65–35 in Specification A 27. The maximum permissible deviation is (0.08 × 0.70 + 0.01) = 0.066. Therefore, the highest acceptable product analysis is 0.766. Similarly, for an 0.20 carbon grade 70–40 in Specification A 27, the maximum manganese content is 1.40; thus, the highest acceptable product analysis is (1.40 + 0.09) = 1.49.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Magnetic Particle Examination

S1.1 Castings shall be examined for surface and near surface discontinuities by magnetic particle examination. The examination shall be in accordance with Practice E 709. Extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S2. Radiographic Examination

S2.1 Castings shall be examined for internal defects by means of X rays or gamma rays. The procedure shall be in accordance with Guide E 94, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 446, E 186, or E 280. Extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S3. Liquid Penetrant Examination

S3.1 Castings shall be examined for surface discontinuities by means of liquid penetrant examination. The examination shall be in accordance with Practice E 165. Areas to be inspected, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S4. Ultrasonic Examination

S4.1 Castings shall be examined for internal defects by means of ultrasonic examination. The examination procedure shall be in accordance with Practice A 609/A 609M. Extent of examination, methods of testing, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S5. Examination of Weld Preparation

S5.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the examination method specified for the casting. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E 125, of Degree 2 in sections up to 2 in. (50.8 mm) thick and of Degree 3 in sections over 2 in. thick shall be acceptable.

S6. Certification

S6.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification (including year date) and was found to meet the requirements.

S7. Prior Approval of Major Weld Repairs

S7.1 Major weld repairs as defined and agreed upon between the manufacturer and purchaser shall be subject to the prior approval of the purchaser.

S8. Marking

S8.1 The manufacturer's name or identification mark and the pattern number shall be cast or stamped on all castings. When further specified, the heat numbers or serial numbers shall be marked on individual castings.

S9. Charpy Impact Test

S9.1 Charpy impact test properties shall be determined on each heat from a set of three Charpy V-notch specimens made from a test coupon in accordance with Test Methods and Definitions A 370, and tested at a test temperature agreed upon by the manufacturer and purchaser. The acceptance requirements shall be either

energy absorbed, lateral expansion, or percent shear area, or all three, and shall be that agreed upon between the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S9.2 *Absorbed Energy* — Average energy value of three specimens shall be not less than specified, with not more than one value permitted to fall below the minimum specified and no value permitted below the minimum specified for a single specimen.

S9.3 *Lateral Expansion* — Lateral expansion value shall be agreed upon between the manufacturer and purchaser.

S9.4 *Percent Shear Area* — Percent shear area shall be agreed upon between the manufacturer and purchaser.

S10. Hardness Test

S10.1 Hardness measurements at specified locations of the castings shall be made in accordance with Test Methods and Definitions A 370 and reported.

S11. Specified Ferrite Content Range

S11.1 The chemical composition of the heat shall be controlled such that the ferrite content, as determined by the chemical composition procedure of Practice A 800/A 800M, shall be in conformance with the specified ferrite content range.

S11.2 The specified ferrite content range shall be as agreed upon between the manufacturer and the purchaser. The minimum specified ferrite content range shall be 10% with the minimum ferrite content being no lower than the percent necessary to achieve the minimum mechanical properties required for the alloy.

S11.3 Should the purchaser wish to have the ferrite content determined by either magnetic response or metallographic methods, the purchaser should impose Supplementary Requirement S1 or S2 of Practice A 800/A 800M.

S12. Test Report

S12.1 The manufacturer shall supply a test report to the purchaser giving the results of all tests performed including chemical analysis.

S13. Unspecified Elements

S13.1 Chemical analysis and limits for elements not specified for the grade ordered shall be as agreed upon between the manufacturer and purchaser.

S14. Tension Test from Castings

S14.1 In addition to the tension test required by the material specification, test material shall be cut from the casting. The mechanical properties and location for the test material shall be agreed upon by the manufacturer and purchaser.

S15. Alternate Tension Test Coupons and Specimen Locations for Castings (in lieu of Test Bars Poured from Special Blocks)

S15.1 Test blocks may be cast integrally with the castings or as separate blocks. Test blocks shall be heat-treated together with the castings they represent.

S15.2 In the following, the casting thickness, *T*, is the maximum thickness of the casting exclusive of padding added for directional solidification, flanges, appendages, and sections designated by the designer as noncritical. The order, inquiry, and drawing shall designate what the test dimension, *T*, is for the casting.

S15.3 One of the following shall apply:

S15.3.1 The longitudinal centerline of the test specimen shall be taken at least $\frac{1}{4}T$ from the *T* dimension surface and all of the gage length must be at least 1*T* from any other heat-treated surface, exclusive of the surface opposite the *T* dimension surface. (See Fig. S15.1(a).) For cylindrical castings, the longitudinal centerline of the specimens shall be taken at least $\frac{1}{4}T$ from the outside or inside and all of the gage length must be at least *T* from the as-heat-treated end. (See Fig. S15.1(b).) For ferritic and martensitic castings, partial severing of test blocks prior to final heat treatment is permitted.

S15.3.2 Where separately cast test coupons are used, the dimension shall not be less than 3*T* by 3*T* by *T* and each specimen shall meet the requirements of S15.3.1, except that when *T* exceeds 5 in. [125 mm], the dimension may be 15 by 15 by 5 in. [375 by 375 by 125 mm], by agreement between the manufacturer and the purchaser. The test coupon shall be of the same heat of steel and shall receive substantially the same casting practices as the production casting it

represents. Centrifugal castings may be represented by statically cast coupons. (See Fig. S15.2.)

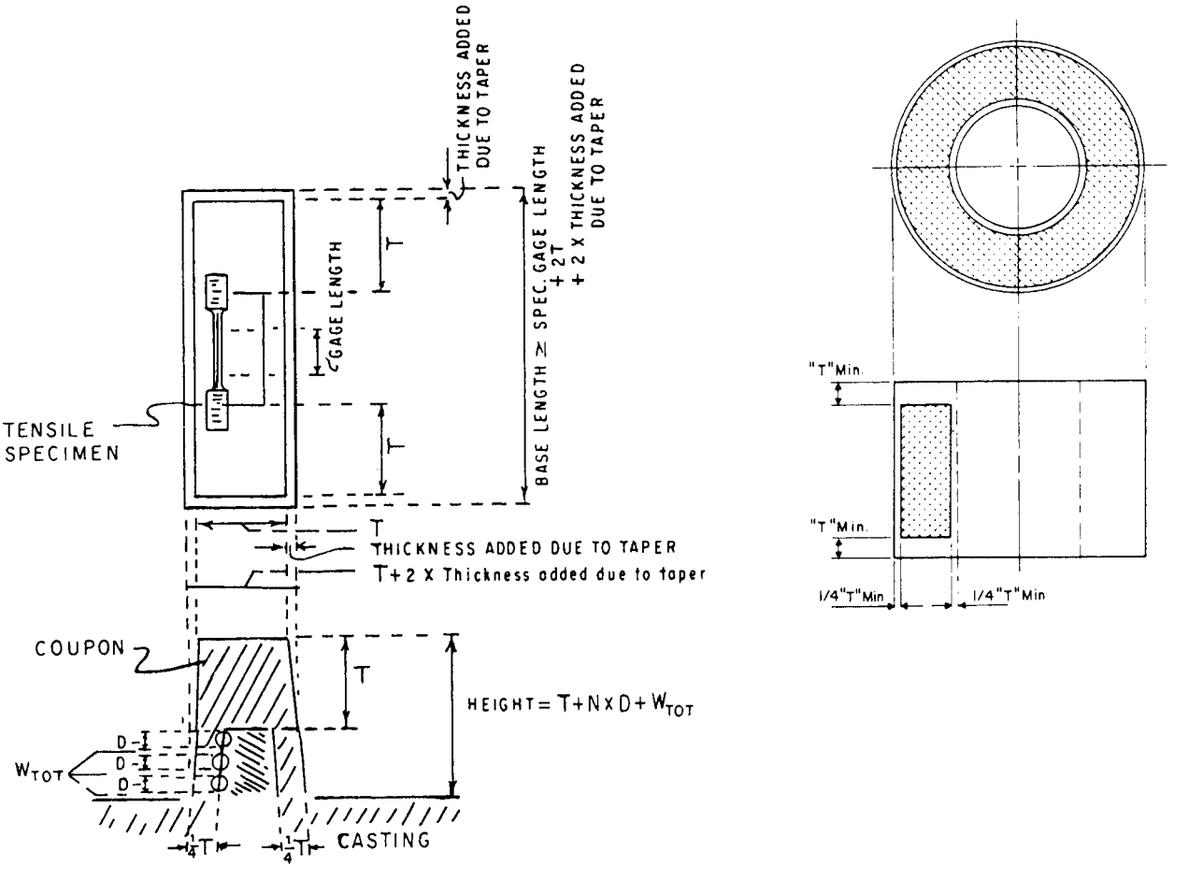
S15.3.3 When agreed upon by the manufacturer and the purchaser, castings that are cast or machined to essentially the finished configuration prior to heat-treatment shall have test specimens removed from a prolongation or other stock on the casting at a location below the nearest heat-treated surface indicated on the order. The specimen location shall be at a distance below the nearest heat-treated surface equivalent to at least the greatest distance that the indicated high-tensile-stress surface will be from the nearest heat-treated surface and a minimum of twice this distance from a second heat-treated surface, except that the test specimens shall be no nearer than ¾ in. [19 mm] to a heat-treated surface and 1½ in. [38 mm] from a second heat-treated surface. (See Fig. S15.3.)

S15.3.4 Where specimens are to be removed from the body of quenched and temperated castings, either the requirements of S15.3.1 shall be met or a steel thermal buffer pad or thermal insulation or other thermal barriers shall be used during heat-treatment. Steel thermal buffer pads shall be a minimum of *T* by *T* by 3*T* in length and shall be joined to the casting surface by a partial penetration weld completely sealing the buffered surface. Test specimens shall be removed from the casting in a location adjacent to the center third of the buffer pad. They shall be located at a minimum distance of ½ in. [13 mm] from the buffered surface and ¼*T* from other heat-treated surfaces (see Fig. S15.4). When thermal insulation is used, it shall be applied adjacent to the casting surface where the test specimens are to be removed. The producer shall demonstrate that the cooling rate of the test specimen location is no faster than that of specimens taken by the method described in S15.3.1.

S16. Weld Repair Charts

S16.1 Major weld repairs shall be documented by means of sketches or photographs, or both, showing the location and major dimensions of cavities prepared for welding. Documentation shall be submitted to the purchaser at the completion of the order.

S16.2 A weld repair shall be considered major when it is made to correct leakage on hydrostatic testing, or when the depth of the cavity prepared for welding exceeds 20% of the actual wall thickness or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 in.^{2} [65 cm^2].

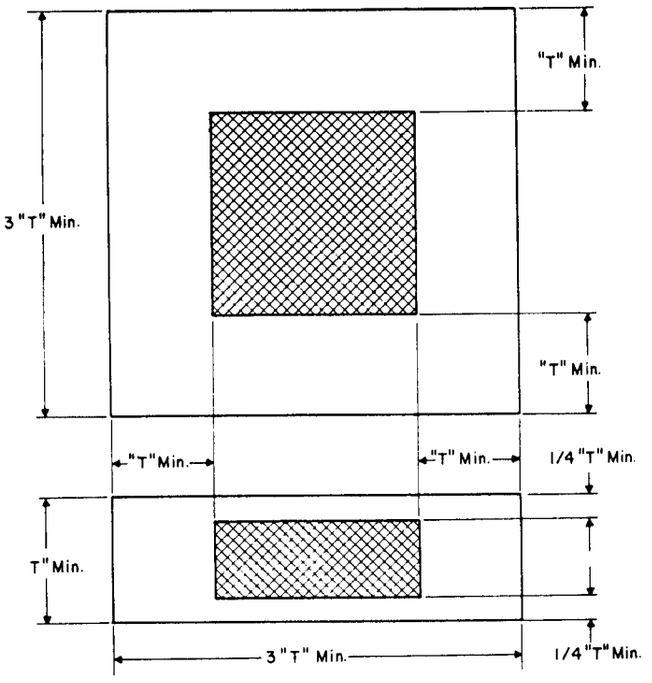


Minimum length of the base—Specimen gage length + 2x*T* + 2x the thickness due to the tapes.
Minimum width of the base—*T* + 2x the thickness added due to the taper.
Minimum height—*T* + *NxD* + W_{tot}.
The taper is to be selected by the producer for ease of drawing the pattern from the mold.

where:
N = number of specimens to be cut from one side of the coupon,
D = diameter of the specimens, and
W_{tot} = the total width of metal required to remove the coupon from the casting, and to machine specimens from the coupon.

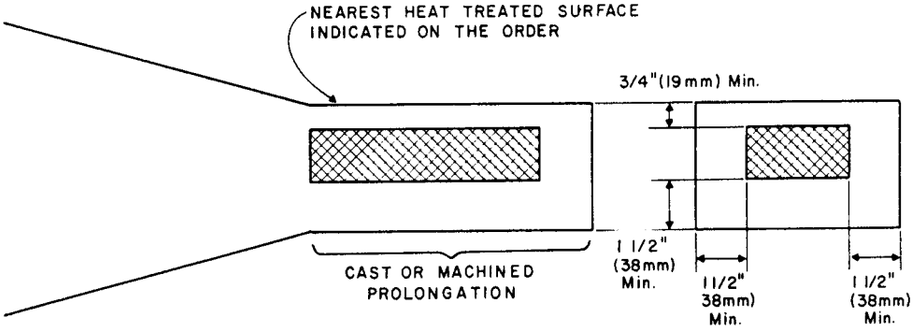
NOTE—Longitudinal axis and gage length of test specimen must be within shaded zone.

FIG. S15.1 SPECIMEN FROM CASTING



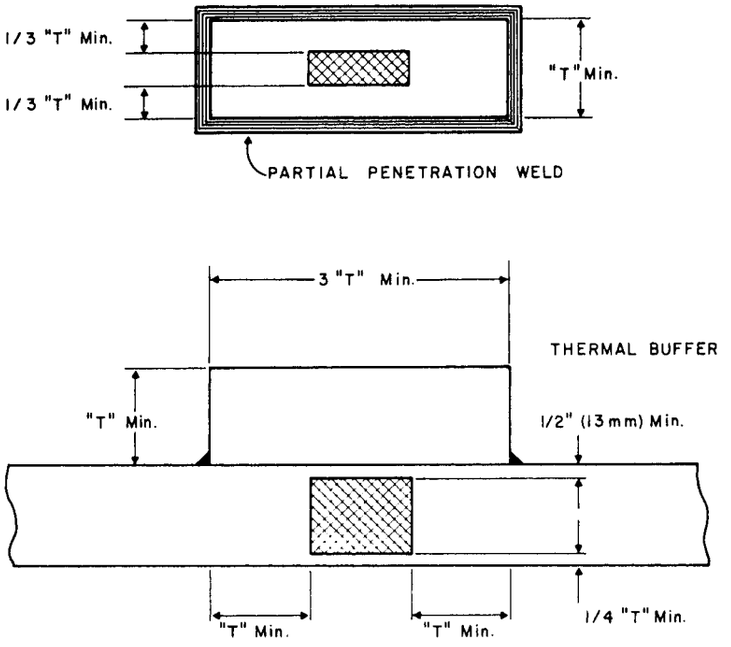
NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S15.2 SEPARATELY CAST BLOCK



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S15.3 PROLONGATION TEST SPECIMEN



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

FIG. S15.4 THERMAL BUFFER PAD

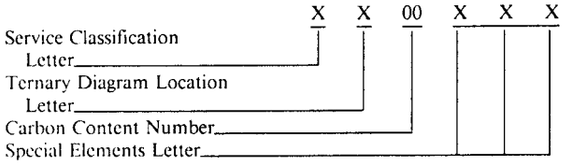
APPENDIX

(Nonmandatory Information)

X1. ALLOY DESIGNATIONS FOR CAST STAINLESS STEELS

X1.1 Cast stainless steels are usually specified on the basis of composition using the alloy designation system established by the Alloy Casting Institute (ACI). The ACI designations, for example, CF8M, have been adopted by ASTM and are preferred for cast alloys over the designations used by the American Iron and Steel Institute for similar wrought steels.

X1.2 This nomenclature system has served successfully to accommodate changes in old alloys and to designate new ones.



X1.2.1 *Service Classification Letter* — The first letter of the cast stainless steel designation system identifies the intended service application of the alloy. The letter C indicates corrosion-resistant service, and the letter H indicates the heat-resistant service at and above 1200°F [649°C].

X1.2.2 *Ternary Diagram Location Letter* — The second letter indicates the approximate location of the nickel and chromium contents of the alloy grade on the FeCrNi ternary diagram shown in Fig. X1.1.

X1.2.3 *Carbon Content Number* — For C service classifications, this single or dual digit numeral represents the maximum carbon content in units of 0.01%. For H service classifications, this number represents the midpoint of the range of carbon content in terms of 0.01% with a ±0.05% limit.

X1.2.4 *Special Elements Letter* — Additional letters following the numeral represent special chemical elements in the alloy grade, such as M for molybdenum, C for columbium, Cu for copper, W for tungsten. There are two exceptions; the letter A indicates Controlled Ferrite, and the letter F indicates Free Machining.

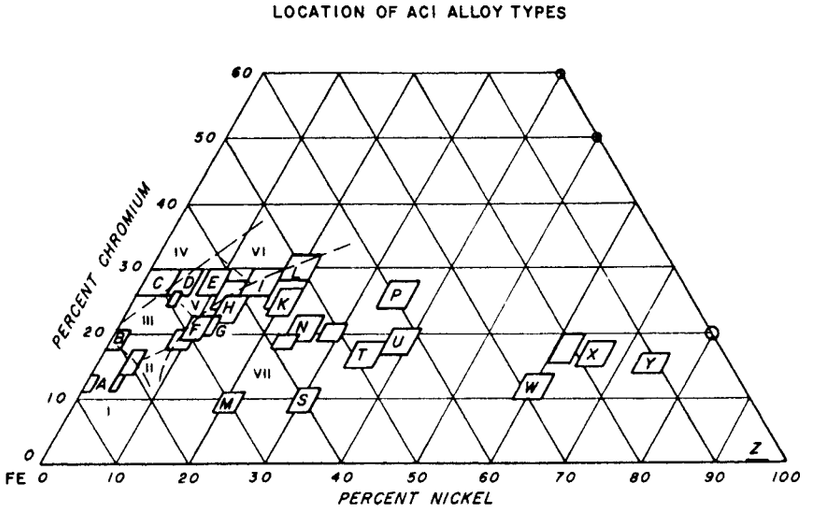
X1.3 In Fig. X1.1, unlettered Ni-Cr ranges are associated with the nearest lettered location. They may be the result of differences between corrosion and heat-resistant types, or because of the influence of additional elements, for example, the precipitation hardening grade CB-7Cu.

X2. WROUGHT ALLOYS SIMILAR TO CASTING ALLOYS IN SPECIFICATIONS A 494, A 743, A 744, A 747 AND A 890 98

X2.1 The following table is provided for the user of the above listed specifications as an aid in selecting cast alloys which are similar in chemical composition to wrought alloys. It is not intended to imply that the cast alloy would have the same mechanical, physical or corrosion properties as the indicated wrought alloy.

Nominal Composition	ASTM Casting Specification	Casting Grade Designation	UNS Number	Similar Wrought Alloy	UNS Number
11Cr-7Ni	A 743	CA-6N	J91650	. . .	. . .
13Cr-4Ni	A 743	CA-6NM	J91540	F-6NM	S41500
13Cr	A 743	CA-15	J91150	410	S41000
13Cr	A 743	CA-15M	J91151	. . .	. . .
12Cr-Mo-V-W	A 743	CA28MWV	J91422	422	S42200
13Cr	A 743	CA-40	J91153	420	S42000
13Cr-S	A 743	CA-40F	J91154	420F	S42020
19Cr-1Ni	A 743	CB-30	J91803	442	S44200
16Cr-4Ni-4Cu	A 747	CB7Cu-1	J92180	17-4	S17400
15Cr-5Ni-3Cu	A 747	CB7Cu-2	J92110	15-5	S15500
27Cr	A 743	CC-50	J92615	446	S44600
25Cr-5Ni-3Mo-2Cu-N	A 743, A 744, A 890	1A & CD-4MCu	J93370	225	S32550
24Cr-10Ni-3Mo-N	A 890	2A & CE-8MN	J93345	. . .	. . .
25Cr-5Ni-Mo-N	A 890	3A	J93371	. . .	. . .
22Cr-5Ni-3Mo-N	A 890	4A	J92205	2205	S31803
25Cr-7Ni-4Mo-N	A 890	5A	J93404	. . .	. . .
28Cr-9Ni	A 743	CE-30	J93423	. . .	. . .
18Cr-8Ni	A 743, A 744	CF-3	J92500	304L	S30403
16Cr-12Ni-2Mo	A 743, A 744	CF-3M	J92800	316L	S31603
16Cr-12Ni-2Mo-N	A 743	CF-3MN	J92804	316LN	S31653
18Cr-8Ni	A 743, A 744	CF-8	J92600	304	S30400
18Cr-10Ni-Cb	A 743, A 744	CF-8C	J92710	347	S34700
16Cr-12Ni-2Mo	A 743, A 744	CF-8M	J92900	316	S31600
18Cr-8Ni-4Si-N	A 743	CF-10SMnN	J92972	Nitronic[A] 60	S21800
18Cr-8Ni-S	A 743	CF-16F	J92701	303Se	S30300
18Cr-8Ni	A 743	CF-20	J92602	302	S30200
22Cr-13Ni-5Mn	A 743, A 744	CG-6MMN	J93790	Nitronic[A] 50	S20910
18Cr-13Ni-3Mo	A 743, A 744	CG-8M	J93000	317	S31700
21Cr-11Ni	A 743	CG-12	J93001	308	S30800
23Cr-12Ni	A 743	CH-20	J93402	309	S30900
20Cr-18Ni-6Mo	A 743, A 744	CK-3MCuN	J93254	254SMO	S31254
25Cr-20Ni	A 743	CK-20	J94202	310	S31000
29Ni-42Fe-20Cr-Mo-Cu	A 743, A 744	CN-3MN	. . .	6XN	N08367
35Ni-35Fe-20Cr-Cb	A 743, A 744	CN-7M	N08007	Alloy 20	N08020
35Ni-46Fe-15Cr	A 743, A 744	CN-7MS	J94650	. . .	. . .
61Ni-16Mo-16Cr	A 494	CW-2M	N26455	C4	N06455
59Ni-18Mo-18Cr	A 494	CW-6M	N30107	. . .	. . .
60Ni-22Cr-9Mo-3.5Cb	A 494	CW-6MC	N26625	625	N06625
55Ni-17Mo-16Cr-4W	A 494	CW-12MW	N30002	C	N10002
57Ni-13Mo-21Cr	A 494	CX-2MW	N26022	C22	N06022
74Ni-12Cr-4Bi-4Sn	A 494	CY-5SnBiM	N26055	. . .	. . .
72Ni-15Cr-8Fe	A 494	CY-40	N06040	600	N06600
95Ni	A 494	CZ-100	N02100	200	N02200
63Ni-29Cu-4Si	A 494	M-25S	N24025	. . .	. . .
63Ni-29Cu-2Cb	A 494	M-30C	N24130	. . .	. . .
63Ni-29Cu-Si	A 494	M-30H	N24030	. . .	. . .
67Ni-30Cu	A 494	M-35-1	N24135	400	N04400
67Ni-30Cu	A 494	M-35-2	N04020	400	N04400
65Ni-28Mo-2Fe	A 494	N-7M	N30007	B2	N10665
62Ni-28Mo-5Fe	A 494	N-12MV	N30012	B	N10001

[A] Nitronic is a trademark of Armco Steel.



NOTE 1—The approximate areas of microstructures to be expected at room temperature are indicated as follows:
I—Martensite
II—Martensite and untransformed austenite
III—Ferrite plus martensite and untransformed austenite
IV—Ferrite
V—Ferrite plus austenite
VI—Ferrite plus austenite plus sigma
VII—Austenite
NOTE 2—Carbides also may be present depending on carbon content and thermal history.

FIG. X1.1 LETTERS ASSIGNED TO CHROMIUM AND NICKEL RANGES IN ACI DESIGNATION SYSTEM

SPECIFICATION FOR STEEL FORGINGS, GENERAL REQUIREMENTS

SA-788

(Identical with ASTM Specification A 788-94) 98

1. Scope

98 **1.1** This specification covers a group of common requirements that, unless otherwise specified in the individual material specification, shall apply to steel forgings under any of the following specifications issued by ASTM:

ASTM Designation	Title
A 266	Forgings, Carbon Steel for Pressure Vessel Components
A 288	Carbon and Alloy Steel Forgings for Magnetic Retaining Rings for Turbine Generators
A 289	Alloy Steel Forgings for Nonmagnetic Retaining Rings for Generators
A 290	Carbon and Alloy Steel Forgings for Rings for Reduction Gears
A 291	Carbon and Alloy Steel Forgings for Pinions and Gears for Reduction Gears
A 294	Alloy Steel Forgings for Turbine Wheels and Disks
A 336	Steel Forgings, Alloy, for Pressure and High-Temperature Parts
A 372	Carbon and Alloy Steel Forgings for Thin-Walled Pressure Vessels
A 427	Wrought Alloy Steel Rolls for Cold and Hot Reduction
A 469	Vacuum-Treated Steel Forgings for Generator Rotors
A 470	Vacuum-Treated Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts
A 471	Vacuum-Treated Alloy Steel Forgings for Turbine Rotor Disks and Wheels
A 508/A 508M	Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings Pressure Vessels
A 521	Steel Closed-Impression Die Forgings for General Industrial Use
A 541/A 541M	Steel Forgings, Carbon and Alloy, Quenched and Tempered, for Pressure Vessel Components
A 579	Superstrength Alloy Steel Forgings
A 592	High-Strength Quenched and Tempered Low-Alloy Steel Forged Fittings and Parts for Pressure Vessels
A 649/A 649M	Forged Steel Rolls Used for Corrugating Paper Machinery
A 654	Special Requirements for Forgings and Bars for Nuclear and Other Special Applications
A 668/A 668M	Steel Forgings Carbon and Alloy for General Industrial Use
A 723/A 723M	Alloy Steel Forgings for High-Strength Pressure Component Application
A 765/A 765M	Carbon Steel and Low-Alloy Steel Pressure Vessel Component Forgings with Mandatory Toughness Requirements
A 768	Vacuum-Treated 12% Chromium Alloy Steel Forgings for Turbine Rotors and Shafts
A 837	Steel Forgings, Alloy, For Carburizing Applications
A 859/A 859M	Steel Forgings, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum Alloy Steel, for Pressure Vessel Components
A 891	Precipitation Hardening Iron Base Superalloy Forgings for Turbine Rotor Disks and Wheels

1.2 In case of conflict in requirements, the requirements of the individual material specifications shall prevail over those of this specification.

1.3 The purchaser may specify additional requirements (see 4.2.3) that do not negate any of the provisions of either this specification or of the individual material specifications. The acceptance of any such additional

requirements shall be dependent on negotiations with the supplier and must be included in the order.

1.4 If, by agreement, forgings are to be supplied in a partially completed condition, that is, all of the provisions of the product specification have not been filled, then the material marking (see Section 16) and certification (see Section 17) shall reflect the extent to which the product specification requirements have been met.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 833 Practice for Indentation Hardness of Metallic Materials by Comparison Hardness Testers
E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials
E 44 Definitions of Terms Relating to Heat Treatment of Metals
E 112 Test Methods for Determining Average Grain Size
E 165 Practice for Liquid Penetrant Examination
E 428 Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection
E 813 Test Method for J_{Ic}, a Measure of Fracture Toughness

3. Terminology

3.1 *Definitions:*

3.1.1 *steel forging* — the product of a substantially compressive plastic working operation that consolidates the material and produces the desired shape. The plastic working may be performed by a hammer, press, forging machine, ring rolling machine, or forging rolls, and must deform the material to produce an essentially wrought structure. Forgings may be subdivided into the following three classes on the basis of their forging temperatures:

3.1.1.1 *hot-worked forgings* — forgings produced by working at temperatures above the recrystallization temperature for the material.

3.1.1.2 *cold-worked forgings* — forgings produced by plastic working well below the temperature range at which recrystallization of the material occurs. Cold-worked forgings must be made from metal previously hot worked by forging or rolling.

3.1.1.3 *hot-cold-worked forgings* — forgings worked at elevated temperatures slightly below the recrystallization range to increase mechanical strength. Hot-cold-worked forgings must be made from material previously hot worked by forging or rolling. A hot-cold-worked forging may be produced in one continuous operation wherein the material is first hot worked then hot-cold-worked by control of the finishing temperature.

3.1.2 Because of differences in manufacture hot rolled, or hot rolled and cold finished bars (semi-finished or finished), billets or blooms are not considered to be forgings.

3.2 *Description of Terms Specific To This Standard:*

3.2.1 *killed steel* — steel deoxidized, either by the addition of strong deoxidizing agents or by vacuum treatment, to reduce the oxygen content to such a level that essentially no reaction occurs between carbon and oxygen during solidification.

3.2.2 *ingot* — the product obtained when molten steel, upon being cast into a mold, is subsequently capable of being wrought in conformance with 3.1. Open-ended molds, that are usually cooled and used, for example, in the continuous casting of steel, are considered to be included in this definition.

3.2.3 *strand casting* — steel from one heat poured into a cooled open-ended mold to form a continuous strand or strands.

3.2.4 *sequential or continuous strand casting* — steel from several heats poured consecutively into a cooled open-ended mold to form a continuous cast product with a change from heat to heat along its length.

3.2.5 *bottom pouring* — steel from a single heat, or from a multiple heat tapped into a common ladle (see 8.1.1 and 8.1.2), introduced into ingot mold(s) such that they are filled from the bottom up. One or more molds can be set up on an individual plate, and more than one plate may be poured in sequence from a heat. The plate is generally constructed such that the molten steel can be ducted through refractory channels to the bottom of each mold on the plate. The steel is poured into a central sprue which is high enough to permit filling the ingot molds to the required level.

4. Ordering Information

4.1 Orders shall include the following information:

4.1.1 Quantity,

4.1.2 Dimensions, including tolerances and surface finishes,

98 **4.1.3** Specification number with type, class, and grade as applicable (year-date) and should include:

4.1.4 Number of copies of the material test report.

4.2 Additional information including the following may be added by agreement with the supplier:

4.2.1 Type of heat treatment when alternative methods are allowed by the material specification,

4.2.2 Supplementary requirements, if any, and

4.2.3 Additional requirements (see 1.4, 16.1.5, and 16.1.6).

4.2.4 Repair welding NOT permitted.

5. Melting Process

5.1 Unless otherwise specified in the material specification, the steel shall be produced by any of the following primary processes: open-hearth, basic-oxygen, electric-furnace, or vacuum-induction (VIM). The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, using electro slag remelting (ESR) or vacuum arc remelting (VAR).

5.2 The molten steel may be vacuum-treated prior to or during pouring of the ingot.

5.2.1 When vacuum treatment of the molten steel is required by the material specification the following conditions shall apply:

5.2.1.1 When the vacuum stream degassing process is used, the vacuum system must be of sufficient capacity to effect a blank-off pressure low enough (usually less than 1000 μm), to break up the normal tight, rope-like stream of molten metal into a wide-angled conical stream of relatively small droplets. The capacity of the system must also be sufficiently high to reduce the initial surge pressure at the start of the pour to a low level within 2 min.

5.2.1.2 When the vacuum-lift process is utilized, the molten metal shall be repeatedly drawn into the evacuated vessel to give a recirculation factor (see Annex A1) of at least 2.5 to ensure thorough degassing and mixing of the entire heat. The evacuation system shall be capable of reducing the pressure surges, which occur each time a new portion of steel is admitted to the vessel to increasingly lower levels, until a blank-off pressure (usually less than 1000 μm) is achieved signifying the end of the degassing treatment.

5.2.1.3 When the ladle degassing process is used, the evacuation system shall be capable of reducing the system vacuum pressure to a low level (usually less than 1000 μm). The molten metal shall be adequately stirred for a sufficient length of time to maximize exposure to the evacuated atmosphere.

5.2.1.4 Other methods of vacuum treatment may be used if the supplier can demonstrate adequate degassing and acceptable properties in the finished forging to the satisfaction of the purchaser.

6. Forging

6.1 Forgings shall be made in accordance with 3.1.

7. Cooling Prior to Heat Treatment

7.1 After forging and before reheating for heat treatment, the forgings shall be allowed to cool in such a manner as to prevent injury and, in the case of ferritic forgings, to permit substantially complete transformation of austenite.

8. Chemical Composition

8.1 *Heat Analysis:*

8.1.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of those elements specified in the material specification. This analysis shall be made from a test sample preferably taken during the pouring of the heat and shall conform to the requirements of the material specification.

8.1.2 When multiple heats are tapped into a common ladle, the ladle chemistry shall apply. The chemical composition thus determined shall conform to the requirements of the material specification.

8.1.3 For multiple-heat ingots, either individual heat analyses or a weighted average (see Annex A2) may be taken. The results of the method used shall conform to the requirements of the material specification.

8.1.4 With the exception of the product from multiple heats sequentially cast in strand casting machines (see 8.1.6), if the test sample taken for a heat analysis is lost or declared inadequate for chemical determinations, the manufacturer may take alternative samples from appropriate locations near the surface of the ingot or forging as necessary to establish the analysis of the heat in question.

8.1.5 *Heat Analysis for Remelted Ingots:*

8.1.5.1 When consumable remelting processes are used, a chemical analysis taken from one remelted ingot (or the product of one remelted ingot) per heat shall be taken as the heat analysis.

8.1.5.2 When electrodes from different master heats are remelted sequentially, an analysis shall be made in each zone of the remelted ingot corresponding to at least one electrode from each master heat. The resultant chemical analysis of each zone shall conform to the requirements of the material specification. The heat analysis of the remelted ingot shall be represented by a weighted average (see Annex A2) of the individual chemical an alyses for each zone.

8.1.5.3 Limits on aluminum content in remelt ingots shall be set as required in the product specification.

8.1.6 For multiple heats sequentially cast in strand casting machines, the heat analysis shall be determined for each individual heat in accordance with 8.1.1, or 8.1.2 if applicable.

8.1.6.1 If, for multiple heats sequentially strand cast, the test sample is lost or declared inadequate for chemical analysis determination, alternative samples, remote from the transition zones, may be taken by the manufacturer from the cast material or product of that heat, as defined in 8.2 or 8.3 as appropriate.

8.2 *Heat Number Assignment for Sequentially Strand Cast Material* — When heats of the same chemical composition are sequentially strand cast, the heat number assigned to the cast product may remain unchanged until all of the steel in the product is from the following heat, except when Supplementary Requirement S3 is invoked.

8.3 *Identification of Material of Different Chemical Composition Ranges, Sequentially Strand Cast* — Because of intermixing in the tun dish, separation and identification of the resultant transition material is required when steels of different chemical composition ranges are sequentially strand cast. The supplier shall remove the transition material by any established procedure that positively separates the grades.

8.4 *Product Analysis:*

8.4.1 An analysis may be made by the purchaser from a forging representing each heat or multiple heat (see 8.1.). Samples for analysis may be taken from the forging or from a full-size prolongation at any point from the midradius to the outer surface of disk or other solid forgings or midway between the inner and outer surfaces of hollow or bored forgings. The analysis may also be taken from a mechanical test specimen or the mechanical test location as defined in the material specification.

8.4.2 The chemical composition thus determined shall conform to the requirements of the forging specification subject to the permissible variations specified in Table 1, for those elements listed in the material specification. Limitations on the application of the allowances in Table 1 may be made in the material specification for specified elements.

8.5 *Residual and Unspecified Elements* — Provisions for the limitation of certain residual and unspecified elements have been made in Supplementary Requirements S1 and S2 respectively.

8.6 Grade substitution is not permitted.

8.7 *Method of Analysis* — Methods included in Test Methods, Practices, and Terminology A 751 shall be used for referee purposes.

9. Heat Treatment

9.1 Heat treatment shall be performed as specified in the product specification. Supplementary Requirement S4 concerns a specialized heat treat process whose application will be controlled in the product specification. See Definitions E 44.

10. Mechanical Testing

10.1 *Test Methods* — All tests shall be conducted in accordance with Test Methods and Definitions A 370.

10.1.1 In addition to the hardness testing provisions of Test Methods and Definitions A 370, comparison hardness testing in accordance with Practice A 833 may be used in determining the hardness of forgings.

10.2 *Retests* — If the results of the tension tests do not conform to the requirements specified, retests are

permitted as outlined in Test Methods and Definitions A 370 or as follows:

10.2.1 If the percentage of elongation or reduction of area of any tension test specimen is less than specified because a flaw becomes evident in the test specimen during testing, a retest shall be allowed provided that the defect was not attributable to ruptures, cracks, or flakes in the steel.

10.2.2 If the average impact energy value meets the specification requirements, but the energy value for one specimen is below the specified minimum value for individual specimens prescribed in the material specification, a retest is permitted. This shall consist of two impact specimens from a location adjacent to and on either side of the specimen that failed. Each of the retested specimens must exhibit an energy value equal to or greater than the minimum average value required by the material specification.

11. Reheat Treatment

11.1 If the results of the initial mechanical tests do not conform to the specified requirements, the forgings may be heat treated (if initially tested in the as-forged condition) or reheat treated (if heat treated prior to initial testing).

12. Repair Welding

12.1 Repair welding of forgings is not permitted unless specifically allowed by the material specification (see also 4.2.4).

13. Dimensions and Finish

13.1 The forgings shall conform to the dimensions, tolerances, and finishes required by the ordering information (4.1.2). Supplementary Requirements S5 or S6, concerning straightening of forgings, may be used.

14. Inspection

14.1 All tests and inspections other than 8.4 shall be made at the place of manufacture, unless otherwise agreed upon.

14.2 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with the material specification.

14.3 Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations.

15. Rejection

15.1 Any rejection based on the presence of an injurious defect found subsequent to acceptance at the manufacturer's works or based on the results of a product analysis made in accordance with 8.4 shall be reported to the manufacturer.

15.2 Disposition of forgings rejected by the purchaser under 15.1 shall be as agreed upon between manufacturer and the purchaser.

16. Certification

16.1 The manufacturer shall furnish to the purchaser the number of copies of the material test report specified in the ordering information (4.1.4). The following items shall be reported:

16.1.1 Purchase order number,

16.1.2 Forging identification number,

16.1.3 Material specification number including the designation and year date, as well as the appropriate class, type, and grade,

16.1.4 Heat number and analysis,

16.1.5 Results of the required acceptance tests for mechanical properties,

16.1.6 Results of any required nondestructive examinations,

16.1.7 Final heat treatment cycle including austenitizing and tempering temperatures and holding times and cooling methods if required by the material specification or 4.2.3,

16.1.8 Extent to which the forging is incomplete with respect to the material specification (see 1.4 and 16.1.7), and

16.1.9 Results of any supplementary and additional test requirements that were specified.

17. Packaging and Package Marking

17.1 Each forging shall be legibly identified as required by the product specification and instructions from the purchaser. When not otherwise defined, each

forging shall be identified by the manufacturer as follows:

17.1.1 Manufacturer's name or symbol.

17.1.2 Manufacturer's identification or heat number.

17.1.3 Material specification number.

17.1.4 The class, grade, and type identification as appropriate.

17.1.5 Purchaser's identification (4.2.3).

17.1.6 Location of stamping (4.2.3).

17.1.7 Incomplete forging (1.4). The marking shall include the suffix Y immediately following the ASTM number, and preceding any other suffix. This suffix shall not be removed until the material specification requirements have been completed and the material test report supplemented.

17.2 Marking shall be done by impression stamping or other acceptable means specified in the material specification or order.

17.3 The specification year date, and revision letter are not required to be marked on the forgings.

18. Keywords

18.1 general delivery requirements; steel forgings—alloy; steel forgings—carbon

TABLE 1
PERMISSIBLE VARIATIONS IN PRODUCT ANALYSIS FOR KILLED STEEL

Note 1 — This table covers permissible variations in product analysis for most of the elements commonly found in killed steels under the jurisdiction of A01.06. This table is applicable only for those elements for which product analysis variations are permitted by the material specification.

Note 2 — Product Cross-Sectional Area is defined as either:
(a) maximum cross-sectional area of rough machined forging (excluding boring),
(b) maximum cross-sectional area of the unmachined forging
(c) maximum cross-sectional area of the billet bloom or slab.

} Area taken at right angles to the axis of the original ingot or billet

		Permissible Variation Over the Specified Maximum Limit or Under the Specified Minimum Limit, %					
Element	Unit or Maximum Specified Range — I	Up to and incl 100 in.^{2} (650 cm^2)[A]	Over 100[A] to 200 in.^{2} incl (650 to 1300 cm^2)	Over 200 in.^{2} to 400 in.^{2} incl (1300 to 2600 cm^2)	Over 400 in.^{2} to 800 in.^{2} incl (2600 to 5200 cm^2)	Over 800 in.^{2} to 1600 in.^{2} incl (5200 to 10300 cm^2)	Over 1600 in.^{2} (over 10300 cm^2)
Carbon	Up to and incl 0.05	0.005	0.005	0.005	0.01	0.01	0.01
	0.06 to 0.10, incl	0.01	0.01	0.01	0.01	0.01	0.01
	0.11 to 0.25, incl	0.02	0.03	0.03	0.04	0.05	0.05
	0.26 to 0.55, incl	0.03	0.04	0.04	0.05	0.06	0.06
	0.56 and over	0.04	0.05	0.05	0.06	0.07	0.07
Manganese	Up to and incl 0.90	0.03	0.04	0.05	0.06	0.07	0.08
	0.91 and over	0.06	0.06	0.07	0.08	0.08	0.09
Phosphorus	Up to and incl 0.05	0.008	0.008	0.010	0.010	0.015	0.015
Sulfur	Up to and incl 0.030	0.005	0.005	0.005	0.005	0.006	0.006
	0.031 to 0.060 incl	0.008	0.010	0.010	0.010	0.015	0.015
Silicon	Up to and incl 0.35	0.02	0.03	0.04	0.04	0.05	0.06
	0.36 and ovr	0.05	0.06	0.06	0.07	0.07	0.08
Nickel	Up to and incl 1.00	0.03	0.03	0.03	0.03	0.03	0.03
	1.01 to 2.00, incl	0.05	0.05	0.05	0.05	0.05	0.05
	2.01 to 5.30, incl	0.07	0.07	0.07	0.07	0.07	0.07
	5.31 to 10.00, incl	0.10	0.10	0.10	0.10	0.10	0.10
	10.01 and over	0.15	0.15	0.15	0.15	0.15	0.15
Chromium	Up to and incl 0.90	0.03	0.04	0.04	0.05	0.05	0.06
	0.91 to 2.10, incl	0.05	0.06	0.06	0.07	0.07	0.08
	2.11 to 10.00, incl	0.10	0.10	0.12	0.14	0.15	0.16
	10.01 to 15.00, incl	0.15	0.15	0.15	0.17	0.17	0.19
	15.01 to 20.00, incl	0.20	0.20	0.20	0.22	0.24	0.24
	20.01 and over	0.25	0.25	0.25	0.27	0.27	0.29
Molybdenum	Up to and incl 0.20	0.01	0.02	0.02	0.02	0.03	0.03
	0.21 to 0.40, incl	0.02	0.03	0.03	0.03	0.04	0.04
	0.41 to 1.15, incl	0.03	0.04	0.05	0.06	0.07	0.08
	1.16 to 5.50, incl	0.05	0.06	0.08	0.10	0.12	0.12
Vanadium	Up to and incl 0.10	0.01	0.01	0.01	0.01	0.01	0.01
	0.11 to 0.25, incl	0.02	0.02	0.02	0.02	0.02	0.02
	0.26 to 0.50, incl	0.03	0.03	0.03	0.03	0.03	0.03
	0.51 to 1.25, incl	0.04	0.04	0.04	0.04	0.04	0.04
Columbium (Niobium)	Up to and incl 0.14	0.02	0.02	0.02	0.02	0.03	0.03
	0.15 to 0.50, incl	0.06	0.06	0.06	0.06	0.07	0.08
Titanium	Up to and incl 0.85	0.05	0.05	0.05	0.05	0.05	0.05
Cobalt	Up to and incl 0.25	0.01	0.01	0.01	0.01	0.01	0.01
	0.25 to 5.00, incl	0.07	0.07	0.07	0.08	0.08	0.09
	5.01 to 10.00, incl	0.14	0.14	0.14	0.16	0.16	0.18
Tungsten	Up to and incl 1.00	0.05	0.05	0.05	0.06	0.06	0.07
	1.01 to 4.00, incl	0.09	0.09	0.10	0.12	0.12	0.14
Copper	Up to and incl, 1.0	0.03	0.03	0.03	0.03	0.03	0.03
	1.01 to 2.00, incl	0.05	0.05	0.05	0.05	0.05	0.05
	2.01 to 5.00, incl	0.07	0.07	0.07	0.07	0.07	0.07
Aluminum	Up to and incl 0.05	0.01	0.01	0.02	0.02	0.03	0.03
	0.06 to 0.15, incl	0.02	0.02	0.02	0.03	0.03	0.03
	0.16 to 0.50, incl	0.05	0.05	0.06	0.07	0.07	0.08
	0.50 to 2.00, incl	0.10	0.10	0.10	0.12	0.12	0.14
Zirconium	Up to and incl 0.15	0.01	0.01	0.01	0.01	0.01	0.01
Nitrogen	Up to 0.02 incl	0.005	0.005	0.005	0.005	0.005	0.005
	Over 0.02 to 0.19, incl	0.01	0.01	0.01	0.01	0.01	0.01
	Over 0.19 to 0.25, incl	0.02	0.02	0.02	0.02	0.02	0.02
	Over 0.25 to 0.35, incl	0.03	0.03	0.03	0.03	0.03	0.03
	Over 0.35 to 0.45, incl	0.04	0.04	0.04	0.04	0.04	0.04

[A] When the product size range up to 100 in.^{2} is deleted, then the 100 to 200-in.^{2} column shall be changed to read up to and including 200 in.^{2}

SUPPLEMENTARY REQUIREMENTS (GENERAL)

The following supplementary general requirements are common to the forging specifications listed in this specification. *Those which are considered to be suitable for use in individual specifications are listed by number and title in that specification.* These and other limitations or tests may be performed by agreement between the supplier and purchaser. The additional requirements shall be specified in the order, and shall be completed by the supplier before the shipment of the forgings.

S1. Residual Elements

S1.1 Small quantities of certain unspecified elements may be present in carbon and low alloy steel forgings. These elements are considered as incidental and may be present to the following maximum amounts:

Copper	0.35%
Nickel	0.30%
Chromium	0.25%
Molybdenum	0.10%
Vanadium[A]	0.03%

[A] Unless supplementary requirement S2 is required.

S2. Unspecified Elements

S2.1 Vanadium used for grain refinement or deoxidation shall not exceed 0.08%.

S3. Sequential or Continuous Strand Casting

S3.1 When multiple heats of the same chemical composition range are sequentially strand cast, the heats shall be separated by an established procedure such that intermix material will not be supplied.

S4. Intercritical Heat Treatment

S4.1 The austenitizing stage in the heat treatment of ferritic forgings is intended to be done at suitable temperatures above the upper critical temperature (Ac_3) for the heat of steel involved, that is, full austenitization. However, when multiple austenitizing stages are used the temperature for the last may be set between the upper (Ac_3) and lower (Ac_1) critical temperature for partial austenitizing. Such cycles shall be followed by tempering within the temperature limits required by the material specification.

S5. Straightening of Forgings

S5.1 Unless otherwise specified by Supplementary Requirement S6, straightening of forgings after heat treatment for properties shall be performed at a temperature which is not more than 100°F (55°C) below the final tempering temperature. Following straightening, forgings shall be stress relieved at a temperature of 50 to 100°F (30 to 55°C) below the final tempering temperature and shall be reported on the material test report. Any straightening performed before heat treatment for properties does not require an intermediate stress-relief heat treatment.

S6. Post-Heat Treatment Straightening of Forgings

S6.1 Straightening after heat treatment for specified properties is not permitted without prior approval by the purchaser.

S7. Fracture Toughness Test

S7.1 Test Method E 813 shall be used in evaluating the fracture toughness of forgings. Location of specimens and test requirements shall be as agreed upon between the purchaser and supplier.

S8. Vacuum Degassing

S8.1 The vacuum degassing requirements of 5.2 shall apply.

S9. Vacuum Carbon Deoxidation

S9.1 The molten steel shall be vacuum carbon deoxidized (VCD) during processing, in which case the silicon content shall be 0.10% maximum.

S10. Restricted Phosphorus and Sulfur, Levels A or B

S10.1 For level A, the phosphorus and sulfur levels shall be limited as follows:

		Heat	Product
Level A	P	0.015% maximum	0.018% maximum
	S	0.018% maximum	0.021% maximum

S10.2 For level B the phosphorus and sulfur levels shall be limited to the following:

		Heat	Product
Level B	P	0.012% maximum	0.015% maximum
	S	0.015% maximum	0.018% maximum

S11. Restricted Copper, Levels A or B

S11.1 For level A, the heat and product analyses limits for copper shall be 0.15% maximum.

S11.2 For level B, the heat and product analyses limits for copper shall be 0.10% maximum.

S12. Tension Specimens for Hubbed Flanges and Tube Sheets

S12.1 For hubbed tube sheets and flanges to be used in ASME Boiler and Pressure Vessel Code construction, an axial tension specimen shall be taken as close as possible to the hub and either inboard or outboard of it, using a sub size specimen if necessary. The longitudinal axis of the specimen shall be parallel to the length of the hub, as shown in Fig. S1.

S12.2 By agreement with the purchaser, this test orientation may replace a specified tension test specimen, provided that other location criteria are met.

S13. Charpy Impact Tests

S13.1 Charpy impact tests shall be made. The number, orientation and location of the tests shall be specified along with the test temperature and the applicable acceptance criteria for absorbed energy, fracture appearance, lateral expansion, or both.

S13.2 The specimens shall be machined and tested in accordance with Test Methods and Definitions A 370.

S14. Charpy V Notch Impact Transition Curve

S14.1 Sufficient impact tests shall be made from the forging material to establish a transition temperature curve based upon one or several of the following criteria:

S14.1.1 Absorbed energy (ft·lbf (J)) (See Test Methods E 23),

S14.1.2 Fracture appearance (see Supplement 5 of Test Methods and Definitions A 370), or

S14.1.3 Lateral expansion.

S14.1.4 The test temperature range shall be wide enough to establish the upper and lower shelf energies, with sufficient testing at intermediate temperatures to permit a smooth curve to be plotted. A minimum test temperature may be set by agreement instead of establishing the lower shelf temperature. The upper shelf energy level is defined as having at least 95% fibrous fracture and the lower shelf level is defined as showing 5% or less fibrous fracture.

S14.2 The purchaser shall furnish the manufacturer with details of sample location, number of specimens, heat treatments, and information to be derived from the test.

S15. Grain Size

S15.1 When a grain size range is required, it shall be specified in the ordering information as heat treated or austenitic, and shall be determined by an agreed-upon method from Test Methods E 112.

S15.2 Samples for grain size estimation from heat treated products shall be taken from the tension test specimen location.

S16. Rough Machining and Boring

S16.1 The position of the rough machining and boring in the manufacturing sequence shall be specified by the purchaser, particularly with regard to heat treatment for mechanical properties.

S17. Simulated Post-Weld Heat Treatment of Mechanical Test Samples

S17.1 All test coupons shall be subjected to single or multiple heat treatments at subcritical temperatures prior to testing. Such treatments are intended to simulate post-weld or other treatments to which the forgings

will be subjected during subsequent fabrication. The purchaser shall furnish the manufacturer with details of the desired heat treatment for the test coupons, including temperatures, times and cooling rates.

S18. Magnetic Particle Examination

S18.1 All accessible surfaces of the finished forging shall be subject to magnetic particle examination in accordance with Test Method A 275/A 275M.

S18.2 Unless otherwise agreed upon between the manufacturer and the purchaser the wet continuous method shall be used.

S18.2.1 The following conditions are subject to rejection or removal:

S18.2.1.1 Indications with major dimension exceeding $^{3}/_{16}$ in. (4.8 mm).

S18.2.1.2 Four or more indications exceeding $^{1}/_{16}$ in. (1.6 mm) in major dimensions that are aligned and separated by $^{1}/_{16}$ in. or less end to end.

S18.2.1.3 Ten or more indications exceeding $^{1}/_{16}$ in. (1.6 mm) in major dimensions contained in any 6 in.^{2} (39 cm^2) of surface, with the major dimension of this area not to exceed 6 in. (150 mm). The area shall be taken in the most unfavorable location relative to the indications being evaluated.

S19. Liquid Penetrant Examination

S19.1 All accessible surfaces of the finished forging shall be subject to liquid penetrant examination in accordance with Practice E 165. The penetrant system to be used shall be agreed upon between the manufacturer and purchaser.

S19.2 The following conditions are subject to rejection or removal.

S19.2.1 Indications with major dimensions exceeding $^{3}/_{16}$ in. (4.8 mm).

S19.2.2 Four or more indications exceeding $^{1}/_{16}$ in. (1.6 mm) in major dimensions that are aligned and separated by $^{1}/_{16}$ in. (1.6 mm) or less end to end.

S19.2.3 Ten or more indications exceeding $^{1}/_{16}$ in. (1.6 mm) in major dimensions contained in any 6 in. (39 cm^2) of surface, with the major dimension in this area not to exceed 6 in. (150 mm). The area shall be taken in the most unfavorable location relative to the indications being evaluated.

S20. Ultrasonic Examination

S20.1 Ultrasonic examination of forgings shall be carried out in accordance with Practice A 388/A 388M.

S20.2 Unless otherwise agreed upon between the manufacturer and the purchaser, acceptance levels BR or DA shall be specified for the longitudinal wave examination and level S for shear wave examination.

Level BR — Longitudinal Wave

S20.2.1 The back reflection method of tuning shall be used in accordance with Practice A 388/A 388M.

S20.2.2 In addition to the reportable conditions of the Recording Section of Practice A 388/A 388M, indications exceeding the resultant back reflection shall be recorded.

S20.2.3 The following conditions are subject to rejection, or repair if applicable.

S20.2.3.1 Complete loss of back reflection accompanied by an indication of a discontinuity. For this purpose, a back reflection less than 5% of full screen height shall be considered complete loss of back reflection.

S20.2.3.2 An indication equal in amplitude to that of the back reflection established in an indication-free portion of the forging.

Level DA — Longitudinal Wave

S20.2.4 Reference blocks of acoustically similar metal shall be used for calibration. Blocks shall meet one of the following requirements:

S20.2.4.1 A comparison of the back reflections between equivalent thicknesses of the reference block material and the actual forging to be tested, without change in instrument setting shall not show a variation in excess of 25%.

S20.2.4.2 The reference blocks shall be manufactured from steel that is similar in chemistry and processing history to the production forging being tested. The reference blocks shall be fabricated in accordance with the procedures of Practice E 428.

S20.2.4.3 For test sections up to and including 12 in. (300 mm) thick, the reference blocks shall contain a $^{1}/_{4}$ in. (6.5 mm) diameter flat-bottom hole; for over 12 in. (300 mm) up to and including 18 in. (300 to

455 mm), the hole diameter shall be $\frac{3}{8}$ in. (9.5 mm); and for over 18 in. (455 mm), it shall be $\frac{1}{2}$ in. (13 mm).

S20.2.4.4 A distance-amplitude correction curve shall be established for the proper grade of steel and specified hole size.

S20.2.4.5 A forging containing one or more indications equal in amplitude to that of the applicable reference hole, when properly corrected for distance, is subject to rejection, or repair if applicable.

Level S—Shear Wave

S20.2.5 Calibration notches, calibration reference, and method of scanning shall be in accordance with Practice A 388/A 388M. Unless otherwise agreed upon, a 60° V-notch shall be used.

S20.2.6 A forging containing a discontinuity which results in an indication exceeding the amplitude of the reference line is subject to rejection.

S20.2.7 The report of the ultrasonic examination shall be in compliance with Practice A 388/A 388M.

S20.2.8 Additional nondestructive examination or trepanning may be employed to resolve questions of interpretation of ultrasonic indications. The manufacturer shall accept responsibility for injurious conditions which will not be removed in final machining.

S21. Additional Test Coupon Heat Treatment

S21.1 When subcritical heat treatment, applied to a completed forging during subsequent fabrication, may affect the mechanical properties of the forging, then coupons for the mechanical testing required by the material specification shall be given a laboratory heat treatment which simulates the anticipated subcritical heat treatment.

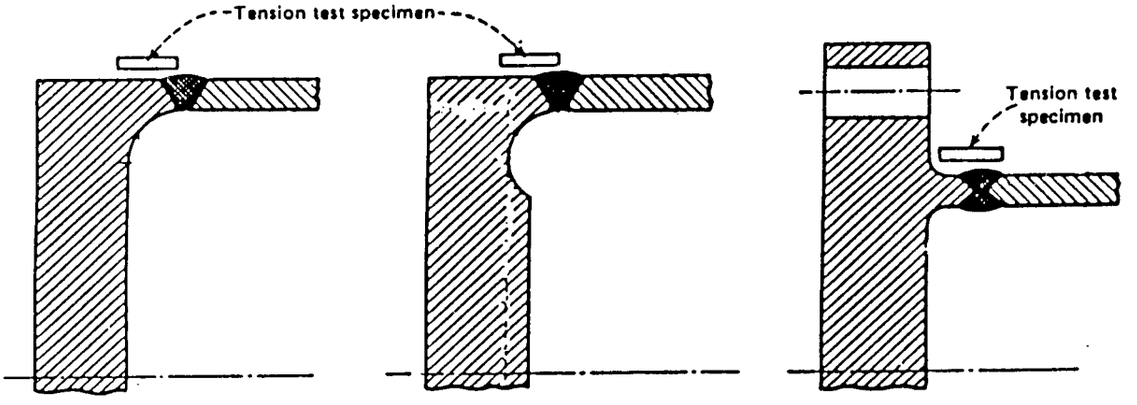
S21.2 The purchaser shall specify the required heat treatment temperature range, minimum time at temperature, and the rates of heating and cooling.

S21.3 The required number of test coupons shall be taken from the forging location described in the material specification.

S21.4 The test specimens shall meet the minimum mechanical test requirements of the material specification, as well as those of any additional tests agreed upon between producer and purchaser, after completion of the test coupon heat treatment.

S21.5 The forgings supplied in accordance with this supplementary requirement shall be marked in accordance with paragraph 17.1.7.

S21.6 The material test reports shall include the heat treatment of the as delivered material and the results of the mechanical tests from the test coupons subjected to the purchaser specified heat treatments which represent fabrication.



[A] Tension test specimens also may be located inboard of the hub.

FIG. S1 TENSION TEST SPECIMENS[A]

ANNEXES

(Mandatory Information)

A1. RECIRCULATION FACTOR

A1.1 The recirculation factor for the vacuum lift process is obtained as follows:

$$\frac{\text{Tons (kg) of Steel Lifted per Cycle} \times \text{Number of Cycles}}{\text{Heat Weight in Tons [kg]}}$$

A2. EXPLANATORY NOTE FOR WEIGHTED AVERAGE ANALYSIS

A2.1 A weighted average analysis is mandatory whenever an ingot is poured from the combination of two or more heats wherein the resultant chemistry of the ingot assumes an identity attributable to each heat involved in the combination. It is necessary to make this determination to ensure that each element in the official chemistry is represented by proportion to its amount in each individual furnace heat. An example of the determination of a weighted average analysis for an ingot made from a three-heat combination pour with varying weights and chemistry involved in each heat is shown below:

	Heat[A] Weight,	Individual Heat Chemistry, %								
Furnace	tons	C	Mn	P	S	Si	Ni	Cr	Mo	V
A	25	0.20	0.50	0.010	0.020	0.34	0.92	0.32	0.12	0.03
B	50	0.25	0.50	0.013	0.015	0.38	0.98	0.32	0.12	0.02
C	50	0.25	0.50	0.015	0.018	0.38	0.94	0.34	0.13	0.02
	125[B]									

Step #1 — Determine furnace factor (FF) for each heat based on weight.

Furnace A = 25/125 = 20%
Furnace B = 50/125 = 40%
Furnace C = 50/125 = 40%

$$FF = \frac{\text{(Individual Fnce Ht. Wt)}}{\text{(Combined Heat Weight)}} \times 100\%$$

Step #2 — Calculate the weighted average for each element. Examples for several elements shown below:

Weighted avg = sum of (% element in each furnace heat × FF)

*Weighted avg of Carbon (weighted avg):

Furnace A — 0.20% × 20% = 0.04%
Furnace B — 0.25% × 40% = 0.10%
Furnace C — 0.25% × 40% = 0.10%

Add to get weighted avg of 0.24%

*Weighted avg of manganese:

Furnace A — 0.50% × 20% = 0.10%
Furnace B — 0.50% × 40% = 0.20%
Furnace C — 0.50% × 40% = 0.20%

Add to get weighted avg of 0.50%

*Weighted avg of phosphorus:

Furnace A — 0.010% × 20% = 0.002%
Furnace B — 0.013% × 40% = 0.0052%
Furnace C — 0.015% × 40% = 0.006%

Add to get weighted avg of 0.013%[C]

[A] This is individual heat contribution to the total ingot weight.
[B] Total ingot weight.
[C] Round to significant figures in accordance with Practice E 380.
*The same procedure is used for all of the other elements.

SPECIFICATION FOR SEAMLESS AND WELDED FERRITIC/AUSTENITIC STAINLESS STEEL TUBING FOR GENERAL SERVICE

SA-789/SA-789M

(Identical with ASTM Specification A 789/A 789M-95.)

1. Scope

1.1 This specification covers grades of nominal wall thickness, stainless steel tubing for services requiring general corrosion resistance, with particular emphasis on resistance to stress corrosion cracking. These steels are susceptible to embrittlement if used for prolonged periods at elevated temperatures.

NOTE 1 — For tubing smaller than $\frac{1}{2}$ in. [12.7 mm] in outside diameter, the elongation values given for strip specimens in Table 1 shall apply. Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in outside diameter or with walls thinner than 0.015 in. [0.4 mm].

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standard:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *SAE Standard:*

SAE J1086

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of Specification A 450/A 450M, unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following as required, to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (seamless or welded tubes),

4.1.3 Grade (Table 2),

4.1.4 Size (outside diameter and nominal wall thickness),

4.1.5 Length (specific or random),

4.1.6 Optional requirements (product analysis for welded tubes, Section 9; hydrostatic or electric test, 10.7),

4.1.7 Test report required (section on Inspection of Specification A 450/A 450M),

4.1.8 Specification designation, and

4.1.9 Special requirements.

5. Manufacture

5.1 The tubes shall be made by the seamless or welded process with no filler metal added.

6. Heat Treatment

6.1 All tubes shall be furnished in the heat-treated condition in accordance with the procedures shown in Table 3.

7. Chemical Composition

7.1 The steel shall conform to the chemical requirements prescribed in Table 2.

8. Product Analysis

8.1 An analysis of either one billet or one length of flat-rolled stock or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

8.2 A product analysis tolerance of Table A1.1 in Specification A 480/A 480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04% or less.

8.3 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock, or tubes shall be made. Both retests for the elements in question shall meet the requirements of this specification; otherwise all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock, or tubes that do not meet the requirements of this specification shall be rejected.

NOTE 2 — For flange and flaring requirements, the term "lot" applies to all tubes prior to cutting of the same nominal size and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 4.

NOTE 3 — For tension and hardness test requirements, the term "lot" applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed.

9. Mechanical Tests Required

9.1 *Tension Tests* — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 3).

9.2 *Flaring Test* (for Seamless Tubes) — One test shall be made on specimens from one end of one tube from each lot (Note 2) of finished tubes. The minimum expansion of the inside diameter shall be 10%.

9.3 *Flange Test* (for Welded Tubes) — One test shall be made on specimens from one end of one tube from each lot (Note 2) of finished tubes.

9.4 *Hardness Test* — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 3).

9.5 When more than one heat is involved, the tension, flaring, flanging, and hardness test requirements shall apply to each heat.

9.6 *Reverse Flattening Test* — For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

9.7 *Hydrostatic or Nondestructive Electric Test* — Each welded tube shall be subjected to either the hydrostatic or nondestructive electric test. The purchaser may specify which test is to be used. Each seamless tube shall be subjected to the hydrostatic test, or instead of this test, a nondestructive electric test may be used when specified by the purchaser. The hydrostatic test shall be in accordance with Specification A 450/A 450M with the calculated test pressure twice that calculated in accordance with the procedure in the Hydrostatic Test Section of Specification A 450/ A 450M.

10. Tensile and Hardness Properties

10.1 The material shall conform to the tensile and hardness properties prescribed in Table 1.

11. Permissible Variations in Dimensions

11.1 Variations in outside diameter, wall thickness, and length from those specified shall not exceed the amounts prescribed in Table 5.

11.2 The permissible variations in outside diameter given in Table 5 are not sufficient to provide for ovality in thin-walled tubes, as defined in the table. In such tubes, the maximum and minimum diameters at any cross section shall deviate from the nominal diameter by no more than twice the permissible variation in outside diameter given in Table 5; however, the mean diameter at that cross section must still be within the given permissible variation.

12. Surface Condition

12.1 All tubes shall be free of excessive mill scale, suitable for inspection. A slight amount of oxidation will not be considered as scale. Any special finish requirements shall be subject to agreement between the manufacturer and the purchaser.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall indicate whether the tubing is seamless or welded.

14. Keywords

14.1 duplex stainless steel; ferritic/austenitic stainless steel; seamless steel tube; stainless steel tube; steel tube; welded steel tube

TABLE 1
TENSILE AND HARDNESS REQUIREMENTS

UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Hardness, max	
				Brinell	Rockwell C
S31803	90 [620]	65 [450]	25	290	30.5
S31500	92 [630]	64 [440]	30	290	30.5
S32550	110 [760]	80 [550]	15	297	31.5
S31200	100 [690]	65 [450]	25	280	...
S31260 [Note (1)]	100 [690]	65 [450]	25	290	30.5
S32304					
OD 1 in. [25 mm] and under	100 [690]	65 [450]	25	...	...
OD over 1 in. [25 mm]	87 [600]	58 [400]	25	290	30.5
S39274	116 [800]	80 [550]	15	310	...
S32750	116 [800]	80 [550]	15	310	32
S32760	109–130 [750–895]	80 [550]	25	270	...
S32900	90 [620]	70 [485]	20	271	28
S32950 [Note (2)]	100 [690]	70 [480]	20	290	30.5
S39277	120 [825]	90 [620]	25	290	30

NOTES:
(1) Prior to A 789/A 789M - 87, the values for S31260 were: 92 ksi tensile strength, 54 ksi yield strength, and 30% elongation.
(2) Prior to A 789/A 789M - 89, the tensile strength value was 90 ksi for UNS S32950.

TABLE 2
CHEMICAL REQUIREMENTS

UNS Designation [Note (1)]	C	Mn	P	S	Si	Ni	Cr	Mo	N	Cu	Others
S31803	0.030 max	2.0 max	0.030 max	0.020 max	1.0 max	4.50–6.50	21.0–23.0	2.50–3.50	0.08–0.20	. . .	. . .
S31500	0.030 max	1.20–2.00	0.030 max	0.030 max	1.40–2.00	4.25–5.25	18.0–19.0	2.50–3.00	0.05–0.1	. . .	. . .
S32550	0.040	1.5 max	0.040 max	0.030 max	1.0 max	4.50–6.50	24.0–27.0	2.90–3.90	0.10–0.25	1.5–2.5	. . .
S31200	0.030 max	2.0 max	0.045 max	0.030 max	1.0 max	5.50–6.50	24.0–26.0	1.20–2.00	0.14–0.20	. . .	. . .
S31260	0.030 max	1.00 max	0.030 max	0.030 max	0.75 max	5.50–7.50	24.0–26.0	2.50–3.50	0.10–0.30	0.20–0.80	W 0.10–0.50
S32304	0.030 max	2.50 max	0.040 max	0.040 max	1.0 max	3.0–5.5	21.5–24.5	0.05–0.60	0.05–0.20	0.05–0.60	. . .
S39274	0.030 max	1.0 max	0.030 max	0.020 max	0.80 max	6.0–8.0	24.0–26.0	2.50–3.50	0.24–0.32	0.20–0.80	W 1.50–2.50
S32750	0.030 max	1.2 max	0.035 max	0.020 max	0.8 max	6.0–8.0	24.0–26.0	3.0–5.0	0.24–0.32	0.5 max	. . .
S32760	0.05 max	1.00 max	0.030 max	0.010 max	1.00 max	6.00–8.00	24.00–26.00	3.00–4.00	0.20–0.30	0.50–1.00	W 0.50–1.00 40 min [Note (2)]
S32900	0.08 max	1.00 max	0.040 max	0.030 max	0.75 max	2.50–5.00	23.00–28.00	1.00–2.00	. . .	. . .	. . .
S32950	0.03 max	2.00 max	0.035 max	0.010 max	0.60 max	3.50–5.20	26.00–29.00	1.00–2.50	0.15–0.35	. . .	. . .
S39277	0.025 max	0.80 max	0.025 max	0.002 max	0.80 max	6.50–8.00	24.00–26.00	3.00–4.00	0.23–0.33	1.2–2.0	W 0.8–1.2

NOTES:
(1) New designation established in accordance with Practice E 527 and SAE J1086.
(2) % Cr + 3.3 × % Mo + 16 × % N.

TABLE 3
HEAT TREATMENT

UNS Designation	Temperature	Quench
S31803	1870–2010°F [1020–1100°C]	Rapid cooling in air or water
S31500	1800–1900°F [980–1040°C]	Rapid cooling in air or water
S32550	1900°F [1040°C] min	Rapid cooling in air or water
S31200	1920–2010°F [1050–1100°C]	Rapid cooling in water
S31260	1870–2010°F [1020–1100°C]	Rapid cooling in water
S32304	1700–1920°F [925–1050°C]	Rapid cooling in air or water
S39274	1920–2060°F [1025–1125°C]	Rapid cooling in air or water
S32750	1880–2060°F [1025–1125°C]	Rapid cooling in air or water
S32760	2010–2085°F [1100–1140°C]	Rapid cooling in air or water
S32900	1700–1750°F [925–955°C]	Rapid cooling in air or water
S32950	1820–1880°F [990–1025°C]	Air cool
S39277	1975–2155°F [1080–1180°C]	Rapid cooling in air or water

TABLE 4
NUMBER OF TUBES IN A LOT HEAT TREATED BY THE CONTINUOUS PROCESS

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

TABLE 5
PERMISSIBLE VARIATIONS IN DIMENSIONS

Group	Size, Outside Diameter, in. [mm]	Permissible Variations in Outside Diameter, in. [mm]	Permissible Variations in Wall Thickness, [Note (4)] %	Permissible Variations in Cut Length, in. [Note (2)] [mm]		Thin Walled Tubes [Note (3)]
				Over	Under	
1	Up to ½ [12.7], excl	±0.005 [0.13]	±15	⅛ [3]	0	. . .
2	½ to 1½ [12.7 to 38.1], excl	±0.005 [0.13]	±10	⅛ [3]	0	less than 0.065 in. [1.6 mm] nominal
3	1½ to 3½ [38.1 to 88.9], excl	±0.010 [0.25]	±10	3/16 [5]	0	less than 0.095 in. [2.4 mm] nominal
4	3½ to 5½ [88.9 to 139.7], excl	±0.015 [0.38]	±10	3/16 [5]	0	less than 0.150 in. [3.8 mm] nominal
5	5½ to 8 [139.7 to 203.2], incl	±0.030 [0.76]	±10	3/16 [5]	0	less than 0.150 in. [3.8 mm] nominal

NOTES:
(1) When tubes as ordered require wall thicknesses ¾ in. [19 mm] or over, or an inside diameter 60% or less of the outside diameter, a wider variation in wall thickness is required. On such sizes a variation in wall thickness of 12.5% over or under will be permitted. For tubes less than ½ in. [12.7 mm] in inside diameter which cannot be successfully drawn over a mandrel, the wall thickness may vary ±15% from that specified.
(2) These tolerances apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over-tolerances shall be increased by: ⅛ in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft or ½ in. [13 mm], whichever is the lesser.
(3) Ovality provisions of 11.2 apply.

SUPPLEMENTARY REQUIREMENT

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Air-Underwater Pressure Test

S1.1 Each tube, with internal surface clean and dry, shall be internally pressurized to 150 psi [1000 kPa] minimum with clean and dry compressed air while being submerged in clear water.

S1.2 The tube shall be well-lighted, preferably by underwater illumination.

S1.3 Any evidence of air leakage of the pneumatic couplings shall be corrected prior to testing.

S1.4 After holding the pressure for not less than 5 s after the surface of the water has become calm, an inspection shall be made of the entire external surface of the tube.

S1.5 If any tube leaks during the air-underwater test, it shall be rejected. Any leaking areas may be cut out and the tube retested as in S1.1 through S1.4.

SPECIFICATION FOR SEAMLESS AND WELDED FERRITIC/AUSTENITIC STAINLESS STEEL PIPE

SA-790/SA-790M

(Identical with ASTM Specification A 790/A 790M-95.)

1. Scope

1.1 This specification covers seamless and straight-seam welded ferritic/austenitic steel pipe intended for general corrosive service, with particular emphasis on resistance to stress corrosion cracking. These steels are susceptible to embrittlement if used for prolonged periods at elevated temperatures.

1.2 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and when desired, one or more of these may be specified in the order.

1.3 Table X1.1 of this specification lists the dimensions of welded and seamless stainless steel pipe as shown in ANSI B36.19. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 1 — The dimensions designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ANSI Standards:*

B1.20.1 Pipe Threads, General Purpose

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *SAE Standard:*

SAE J1086

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (ferritic/austenitic steel pipe),

4.1.3 Process (seamless or welded),

4.1.4 Grade (Table 1),

4.1.5 Size (NPS designator or outside diameter and schedule number of average wall thickness),

4.1.6 Length (specific or random) (Section 10),

4.1.7 End finish (section on ends of Specification A 530/A 530M),

4.1.8 Optional requirements (Section 8), Supplementary Requirements S1 to S4),

4.1.9 Test report required (section on Certification of Specification A 530/A 530M),

4.1.10 Specification designation, and

4.1.11 Special requirements or exception to the specification.

5. Materials and Manufacture

5.1 *Manufacture:*

5.1.1 The pipe shall be made by the seamless or an automatic welding process, with no addition of filler metal in the welding operation.

5.1.2 At the manufacturer's option, pipe may be either hot-finished or cold-finished.

5.1.3 The pipe shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

5.2 *Discard* — A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

5.3 All pipe shall be furnished in the heat-treated condition as shown in Table 1.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements as prescribed in Table 2.

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified.

8. Product Analysis

8.1 At the request of the purchaser's inspector, an analysis of one billet or one length of flat-rolled stock from each heat, or two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5, incl	200 or fraction thereof
6 and over	100 or fraction thereof

8.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 6.

8.3 If the analysis of one of the tests specified in 7.1 or 8.1 does not conform to the requirements specified in Section 6, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

9. Tensile and Hardness Properties

9.1 The material shall conform to the tensile and hardness properties prescribed in Table 3.

10. Lengths

10.1 Pipe lengths shall be in accordance with the following regular practice:

10.1.1 Unless otherwise agreed upon, all sizes from NPS $\frac{1}{8}$ to and including NPS 8 are available in a length up to 24 ft (Note 2) with the permissible range of 15 to 24 ft (Note 2). Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

NOTE 2 — This value applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

10.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall

be less than the specified length and no more than $\frac{1}{4}$ in. [6 mm] over it.

10.1.3 No jointers are permitted unless otherwise specified.

11. Workmanship, Finish, and Appearance

11.1 The finished pipes shall be reasonably straight and shall have a workmanlike finish. Imperfections may be removed by grinding, provided the wall thickness are not decreased to less than that permitted, in the Permissible Variations in Wall Thickness Section of Specification A 530/A 530M.

12. Mechanical Tests Required

12.1 *Transverse or Longitudinal Tension Test* — One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two pipes for lots of more than 100 pipes.

NOTE 3 — The term "lot" for mechanical tests, applies to all pipe of the same nominal size and wall thickness (or schedule) that is produced from the same heat of steel and subjected to the same finishing treatment (1) in a continuous heat treatment furnace, or (2) in a batch-type heat-treatment furnace equipped with recording pyrometers and automatically controlled within a 50°F [30°C] range, the larger of: *(a)* each 200 ft [60 m] or fraction thereof or, *(b)* that pipe heat treated in the same batch furnace charge.

12.2 *Flattening Test* — For material heat treated in a batch-type furnace, flattening tests shall be made on 5% of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall be made on a sufficient number of pipes to constitute 5% of the lot, but in no case less than two lengths of pipe.

12.2.1 For welded pipe with a diameter equal to or exceeding NPS 10, a transverse guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5% of the lot shall be taken from the pipes or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

12.3 *Hydrostatic Test* — Each length of finished pipe shall be subjected to the hydrostatic test.

12.3.1 The hydrostatic test shall be in accordance with Specification A 530/A 530M. When making the calculations in the Hydrostatic Test Requirements Section of Specification A 530/A 530M, an *S* value 50% of the specified minimum yield strength shall be used.

12.3.2 When specified by the purchaser, a nondestructive electric test in accordance with Specification A 450/A 450M may be used instead of, or in addition to, the hydrostatic test.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include the manufacturer's private identifying mark and whether the pipe is seamless or welded. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

14. Keywords

14.1 duplex stainless steel: ferritic/austenitic stainless steel; seamless steel pipe; stainless steel pipe; steel pipe; welded steel pipe

TABLE 1
HEAT TREATMENT

UNS Designation	Temperature	Quench
S31803	1870–2010°F [1020–1100°C]	Rapid cooling in air or water
S31500	1800–1900°F [980–1040°C]	Rapid cooling in air or water
S31200	1920–2010°F [1050–1100°C]	Rapid cooling in water
S32550	1900°F [1040°C] min	Rapid cooling in air or water
S31260	1870–2010°F [1020–1100°C]	Rapid cooling in water
S32304	1700–1920°F [925–1050°C]	Rapid cooling in air or water
S39274	1920–2060°F [1025–1125°C]	Rapid cooling in air or water
S32750	1880–2060°F [1025–1125°C]	Rapid cooling in air or water
S32760	2010–2085°F [1100–1140°C]	Rapid cooling in air or water
S32900	1700–1750°F [925–955°C]	Rapid cooling in air or water
S32950	1820–1880°F [990–1025°C]	Air cool
S39277	1975–2155°F [1080–1180°C]	Rapid cooling in air or water

TABLE 2
CHEMICAL REQUIREMENTS

UNS Designation [Note (1)]	C	Mn	P	S	Si	Ni	Cr	Mo	N	Cu	Others
S31803	0.030 max	2.0 max	0.030 max	0.020 max	1.0 max	4.50–6.50	21.0–23.0	2.50–3.50	0.08–0.20	. . .	
S31500	0.030 max	1.20–2.00	0.030 max	0.030 max	1.40–2.00	4.25–5.25	18.0–19.0	2.50–3.00	0.05–0.10	. . .	
S32550	0.040 max	1.5 max	0.040 max	0.030 max	1.0 max	4.50–6.50	24.0–27.0	2.90–3.90	0.10–0.25	1.5–2.5	
S31200	0.030 max	2.0 max	0.045 max	0.030 max	1.0 max	5.50–6.50	24.0–26.0	1.20–2.00	0.14–0.20	. . .	
S31260	0.030 max	1.00 max	0.030 max	0.030 max	0.75 max	5.50–7.50	24.0–26.0	2.50–3.50	0.10–0.30	0.20–0.80	W 0.10–0.50
S32304	0.030 max	2.50 max	0.040 max	0.040 max	1.0 max	3.0–5.5	21.5–24.5	0.05–0.60	0.05–0.20	0.05–0.60	
S39274	0.030 max	1.0 max	0.030 max	0.020 max	0.80 max	6.0–8.0	24.0–26.0	2.50–3.50	0.24–0.32	0.20–0.80	W 1.50–2.50
S32750	0.030 max	1.2 max	0.035 max	0.020 max	0.8 max	6.0–8.0	24.0–26.0	3.0–5.0	0.24–0.32	0.5 max	. . .
S32760	0.05 max	1.00 max	0.030 max	0.010 max	1.00 max	6.00–8.00	24.00–26.00	3.00–4.00	0.20–0.30	0.50–1.00	W 0.50–1.00 40 min [Note (2)]
S32900	0.08 max	1.00 max	0.040 max	0.030 max	0.75 max	2.50–5.00	23.00–28.00	1.00–2.00	. . .	. . .	. . .
S32950	0.03 max	2.00 max	0.035 max	0.010 max	0.60 max	3.50–5.20	26.00–29.00	1.00–2.50	0.15–0.35	. . .	
S39277	0.025 max	0.80 max	0.025 max	0.002 max	0.80 max	6.5–8.00	24.00–26.00	3.00–4.00	0.23–0.33	1.2–2.0	W 0.8–1.2

NOTES:
(1) New designation established in accordance with Practice E 527 and SAE J1086.
(2) % Cr + 3.3 × % Mo + 16 × % N.

TABLE 3
TENSILE AND HARDNESS REQUIREMENTS

UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Hardness, max	
				Brinell	Rockwell C
S31803	90 [620]	65 [450]	25	290	30.5
S31500	92 [630]	64 [440]	30	290	30.5
S32550	110 [760]	80 [550]	15	297	31.5
S31200	100 [690]	65 [450]	25	280	...
S31260 [Note (1)]	100 [690]	65 [450]	25	...	...
S32304	87 [600]	58 [400]	25	290	30.5
S39274	116 [800]	80 [550]	15	310	...
S32750	116 [800]	80 [550]	15	310	32
S32760	109–130 [750–895]	80 [550]	25	270	...
S32900	90 [620]	70 [485]	20	271	28
S32950 [Note (2)]	100 [690]	70 [480]	20	290	30.5
S39277	120 [825]	90 [620]	25	290	30

NOTES:
(1) Prior to A 790/A 790M - 87, the values for S31260 were: 92 ksi tensile strength, 54 ksi yield strength, and 30% elongation.
(2) Prior to A 790/A 790M - 89, the tensile strength value was 90 ksi for UNS S32950.

SUPPLEMENTARY REQUIREMENTS FOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe over NPS 5 there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10% of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 6 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10% of the lengths furnished per heat of steel. This applies only to pipe over NPS 8.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crops end may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

APPENDIX

X1. TABLE X1.1 IS BASED ON TABLE 1 OF THE AMERICAN NATIONAL STANDARD FOR STAINLESS STEEL PIPE (ANSI B36.19-1965)

TABLE X1.1
DIMENSIONS OF WELDED AND SEAMLESS STAINLESS STEEL PIPE

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S [Note (1)]		Schedule 10S [Note (1)]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
1/8	0.405	10.29	...	...	0.049 [Note (2)]	1.24	0.068	1.73	0.095	2.41
1/4	0.540	13.72	...	...	0.065 [Note (2)]	1.65	0.088	2.24	0.119	3.02
3/8	0.675	17.15	...	...	0.065 [Note (2)]	1.65	0.091	2.31	0.126	3.20
1/2	0.840	21.34	0.065 [Note (2)]	1.65	0.083 [Note (2)]	2.11	0.109	2.77	0.147	3.73
3/4	1.050	26.67	0.065 [Note (2)]	1.65	0.083 [Note (2)]	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065 [Note (2)]	1.65	0.109 [Note (2)]	2.77	0.133	3.38	0.179	4.55
1 1/4	1.660	42.16	0.065 [Note (2)]	1.65	0.109 [Note (2)]	2.77	0.140	3.56	0.191	4.85
1 1/2	1.900	48.26	0.065 [Note (2)]	1.65	0.109 [Note (2)]	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065 [Note (2)]	1.65	0.109 [Note (2)]	2.77	0.154	3.91	0.218	5.54
2 1/2	2.875	73.03	0.083	2.11	0.120 [Note (2)]	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120 [Note (2)]	3.05	0.216	5.49	0.300	7.62
3 1/2	4.000	101.60	0.083	2.11	0.120 [Note (2)]	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120 [Note (2)]	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109 [Note (2)]	2.77	0.134 [Note (2)]	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134 [Note (2)]	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109 [Note (2)]	2.77	0.148 [Note (2)]	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134 [Note (2)]	3.40	0.165 [Note (2)]	4.19	0.365	9.27	0.500 [Note (2)]	12.70 [Note (2)]
12	12.750	323.85	0.156 [Note (2)]	3.96	0.180 [Note (2)]	4.57	0.375 [Note (2)]	9.52 [Note (2)]	0.500 [Note (2)]	12.70 [Note (2)]
14	14.000	355.60	0.156 [Note (2)]	3.96	0.188	4.78	...	...	...	...
16	16.000	406.40	0.165 [Note (2)]	4.19	0.188	4.78	...	...	...	...
18	18.000	457.20	0.165 [Note (2)]	4.19	0.188	4.78	...	...	...	...
20	20.000	508.00	0.188 [Note (2)]	4.78	0.218 [Note (2)]	5.54	...	...	...	...
22	22.000	558.80	0.188 [Note (2)]	4.78	0.218 [Note (2)]	5.54	...	...	...	...
24	24.000	609.60	0.218 [Note (2)]	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

GENERAL NOTE: The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NOTES:
(1) Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).
(2) These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10-1979).

SPECIFICATION FOR WELDED FERRITIC STAINLESS STEEL FEEDWATER HEATER TUBES

SA-803/SA-803M

(Identical with ASTM Specification A 803/A 803M-96.) 98

1. Scope

1.1 This specification covers welded ferritic stainless steel feedwater heater tubes including those bent, if specified, into the form of U-tubes for application in tubular feedwater heaters.

1.2 The tubing sizes covered shall be $\frac{5}{8}$ to 1 in. [15.9 to 25.4 mm] inclusive, in outside diameter, and average or minimum wall thicknesses of 0.028 in. [0.7 mm] and heavier.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

98 **2.1** *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

3. General Requirements

3.1 Material furnished to this specification shall conform to the applicable requirements of the latest published edition of Specification A 450/A 450M unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following as required to adequately describe the desired material:

4.1.1 Quantity (length or number of pieces),

4.1.2 Material description,

4.1.3 Dimensions (outside diameter, wall thickness (minimum or average wall), and length),

4.1.4 Grade (chemical composition) (Table 1), and

4.1.5 U-bend requirements, if order specifies bending, U-bend schedules or drawings shall accompany the order.

4.2 *Optional Requirements* — Purchaser shall specify if annealing of the U-bends is required or whether tubes are to be hydrotested or air-tested (see 9.5).

4.3 *Supplementary Requirements* — Purchaser shall specify on this purchase order if material is to be eddy-current tested in accordance with Supplementary Requirement S1 or S2, and if special test reports are required, under Supplementary Requirement S3.

5. Materials and Manufacture

5.1 The tube shall be made from flat-rolled steel by an automatic welding process with no addition of filler metal.

5.2 Materials employed in the manufacture of stainless steel strip or tubing that may come in contact with the stainless steel shall be selected to avoid low melting point alloys or materials containing copper, lead, mercury, or sulfur.

6. Cleaning Before Annealing

6.1 All lubricants or coatings used in the manufacture of straight-length tube or in the bending shall be removed from all surfaces prior to any annealing treatments. U-bends on which a lubricant had been applied to the inside surface during bending shall have the cleanness of their inside surface confirmed by blowing close-fitting acetone-soaked felt plugs through 10% of the tubes of each bend radius. Dry, oil-free air or inert gas shall be used to blow the plugs through the tubes. If the plugs blown through any tube show more than a light gray discoloration, all tubes that have had a lubricant applied to the inside surface during bending shall be recleaned. After recleaning 10% of the tubes of each bend radius whose inside surface had been subjected to bending, lubricants shall be retested.

7. Heat Treatment

7.1 All finished straight tubing or straight tubing ready for U-bending shall be furnished in the solution-annealed condition. The annealing procedure shall consist of heating the material to a temperature of 1200°F [650°C] or higher and cooling (as appropriate for the grade) to meet the requirements of this specification.

7.2 If heat treatment of U-bends is specified, it shall satisfy the annealing procedure described in 7.1 and shall be done as follows:

7.2.1 The heat treatment shall be applied to the U-bend area plus approximately 6 in. [150 mm] of each leg beyond the tangent point of the U-bend.

7.2.2 If the heat treatment specified in 7.2 is accomplished by resistance-heating methods wherein electrodes are clamped to the tubes, the clamped areas shall be visually examined for arc burns. Burn indications shall be cause for rejection unless they can be removed by local polishing without encroaching upon minimum wall thickness.

7.2.3 Temperature control shall be accomplished through the use of optical or emission pyrometers, or both. No temperature-indicating crayons, lacquers, or pellets shall be used.

7.2.4 The inside of the tube shall be purged with a protective or an inert gas atmosphere during heating and cooling to below 700°F [370°C] to prevent scaling of the inside surface. The atmosphere should be noncarburizing.

8. Chemical Composition

8.1 *Product Analysis:*

8.1.1 When requested in the purchase order, a product analysis shall be made by the supplier from one tube or coil of steel per heat. The chemical composition shall conform to the requirements shown in Table 1.

8.1.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of this specification; otherwise all remaining material in the heat or lot (Note 1) shall be rejected or at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of this specification shall be rejected.

NOTE 1 — For product analyses and flange requirements, the term "lot" applies to 125 tube groupings, prior to cutting to length, of the same nominal size and wall thickness, produced from the same heat of steel and annealed in a continuous furnace.

9. Mechanical Requirements

9.1 *Tensile Properties:*

9.1.1 The material shall conform to the tensile properties shown in Table 2.

9.1.2 One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 2).

9.2 *Hardness:*

9.2.1 The tubes shall have a hardness number not to exceed those prescribed in Table 3. This hardness requirement is not to apply to the bend area of U-bend tubes which are not heat treated after bending.

9.2.2 Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 2).

NOTE 2 — For tension, hardness, and corrosion test requirements, the term "lot" applies to all tubes prior to cutting to length, of the

same nominal diameter and wall thickness, produced from the same heat of steel and annealed in a continuous furnace at the same temperature, time at heat, and furnace speed.

9.3 *Reverse Flattening Test* — One reverse flattening test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

9.4 *Flange Test* — Flange tests shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

9.5 *Pressure Test* — Each straight tube or each U-tube after completion of the bending and post-bending heat treatment, shall be pressure-tested in accordance with one of the following paragraphs as specified by the purchaser:

9.5.1 *Hydrostatic Test* — Each tube shall be given an internal hydrostatic test in accordance with Specification A 450/A 450M.

98 **9.5.2** *Air Underwater Test* — Each tube shall be air underwater tested in accordance with Specification A 450/A 450M.

10. Corrosion Resisting Properties

10.1 One full section sample 1 in. [25 mm] long from the center of a sample tube of the smallest radius bend that is heat treated shall be tested in the heat treated condition in accordance with the appropriate practice in Practices A 763 for the specified grade, or as agreed upon for TP409.

10.2 One full-section sample 1 in. [25 mm] long from each lot (Note 2) of straight tubes shall be tested in the finished condition in accordance with the appropriate practice in Practices A 763 for the specified grade, or as agreed upon for TP409.

10.3 The appearance of any fissures or cracks in the test specimen when evaluated in accordance with the Evaluation Sections of Practices A 763 indicating the presence of intergranular attack, shall be cause for rejection of that lot.

11. Permissible Variations in Dimensions (Fig. 1)

11.1 Permissible variations from the specified outside diameter shall be in accordance with Specification A 450/A 450M. Those tolerances do not apply to the bent portion of the U-tubes. At the bent portion of a U-tube for $R = 2 \times D$ or greater, neither the major nor minor diameter of the tube shall deviate from the nominal diameter prior to bending by more than 10%. If less than $2 \times D$ is specified, tolerances could be greater.

11.2 *Permissible Variations from the Specified Wall Thickness:*

11.2.1 Permissible variations from the specified minimum wall thickness shall not exceed +20 − 0%.

11.2.2 Permissible variations from the specified average wall thickness are +10% of the nominal wall thickness.

11.2.3 The wall thickness of the tube in the U-bent section shall not be less than value determined by the equation:

$$t_f = \frac{4RT}{4R + D}$$

where:

t_f = wall thickness after bending, in. [mm],
T = specified minimum tube wall thickness, in. [mm],
R = centerline bend radius, in. [mm], and
D = nominal outside tube diameter, in. [mm].

11.3 *Permissible Variations from the Specified Length:*

11.3.1 *Straight Lengths* — The maximum permissible variations for lengths 24 ft [7.3 m] and shorter shall be $+\frac{1}{8}$ in. [+3 mm], −0; for lengths longer than 24 ft [7.3 m], an additional over tolerance of $+\frac{1}{8}$ in. [+3 mm] for each 10 ft [3 m], or fraction thereof, shall be permitted up to a maximum of $+\frac{1}{2}$ in. [+13 mm].

11.3.2 *U-Bends* — In the case of U-tubes, the length of the tube legs as measured from the point of tangency of the bend and the tube leg to the end of the tube leg, shall not be less than specified, but may exceed the specified values by the amount given in Table 4. The difference in lengths of the tube legs shall not be greater than $\frac{1}{8}$ in. [3 mm] unless otherwise specified.

11.4 The end of any tube may depart from square by not more than the amount given in Table 5.

11.5 The leg spacing measured between the points of tangency of the bend to the legs shall not vary from the value (2*R*-specified tube outside diameter) by more than $\frac{1}{16}$ in. [1.5 mm] where R is the center-line bend radius.

11.6 The bent portion of the U-tube shall be substantially uniform in curvature, and not to exceed $\pm 1/16$ in. [±1.5 mm] of the nominal center-line radius.

11.7 Permissible deviation from the plane of bend (Fig. 1) shall not exceed $1/16$ in. [1.5 mm] as measured from the points of tangency.

12. Workmanship, Finish, and Appearance

12.1 Tubing purchased to this specification is intended for use in heat exchangers and will be inserted through close-fitting holes in baffles or support plates, or both, spaced along the tube length. The tube ends will also be inserted into very close-fitting holes in a tubesheet and expanded and may be welded therein. The tubes shall be able to stand expanding and bending without showing cracks and flaws, and shall be finished reasonably straight and suitable for the intended purpose. Surface defects that violate minimum wall requirements shall be cause for rejection.

12.2 The residual chloride salt contamination of the inside and outside surface of the tubing at the time of packing for shipment from the mill shall not exceed a concentration of 1 mg/ft^2 [10.7 mg/m^2] of tube surface. One tube in each 500 pieces shall be checked immediately prior to packing for shipment for chloride salt contamination by a procedure agreed to between the manufacturer and purchaser.

13. Surface Condition

13.1 The straight tubes, after final annealing, shall be pickled using a solution of nitric and hydrofluoric acids followed by flushing and rinsing in water. If bright-annealing is performed, this requirement does not apply.

13.1.1 All tubes shall be free of excessive mill scale, suitable for inspection. A slight amount of oxidation will not be considered as scale. Any special finish requirements shall be subject to agreement between the manufacturer and the purchaser.

13.2 A light oxide scale on the outside surface of U-bend area shall be permitted for tubes that have been electric-resistance heat treated after bending.

14. Nondestructive Test (Electric Test)

14.1 Each straight tube shall be tested after the finish heat treatment by passing it through a nondestructive tester capable of detecting defects on the entire cross section of the tube in accordance with Specification A 450/A 450M.

15. Inspection

15.1 The inspector representing the purchaser shall have entry, at all times, to those areas where inspection and testing is being performed on the purchaser's ordered material. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All required tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

16. Rejection

16.1 Each length of tubing received from the manufacturer may be inspected by the purchaser, and, if it does not meet the requirements of the specification based on the inspection and test method outlined in the specification, the tubing may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

16.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective, shall be set aside, and the manufacturer shall be notified. Disposition of such material shall be a matter for agreement between the manufacturer and the purchaser.

17. Certification

17.1 A test report, signed by an authorized employee or representative of the manufacturer, shall be furnished to the purchaser to indicate the specification and grade, the results of the heat analysis, hardness, and tensile properties. Product analysis will be reported only when requested on the purchase order as provided in 8.1.1.

18. Product Marking

18.1 All tubes shall be marked with the heat number.

18.2 Containers and packages shall be marked or tagged to show the purchaser's order number, the manufacturer's order number, specification, grade, size

and gage of tubing, number of pieces contained in the package, and item number (if appropriate).

19. Packaging

19.1 All tubing shall be packaged and blocked in such a manner as to prevent damage in ordinary handling and transportation. The boxes shall be constructed in such a manner that no nails, staples, screws, or similar fasteners are required to close and secure the box after the tubes have been placed in the box. The box shall be lined with plastic sheet or vapor barrier materials so as to prevent chloride contamination of the tube during handling, transportation, and storage.

19.2 The U-bent tubes shall be arranged in boxes so that the smaller radius bends may be removed without disturbing larger radius bends. Tubes for an item number shall be boxed together.

20. Keywords

98

20.1 feedwater heater tubes; ferritic stainless steel; seamless steel tube; stainless steel tube; steel tube; welded steel tube

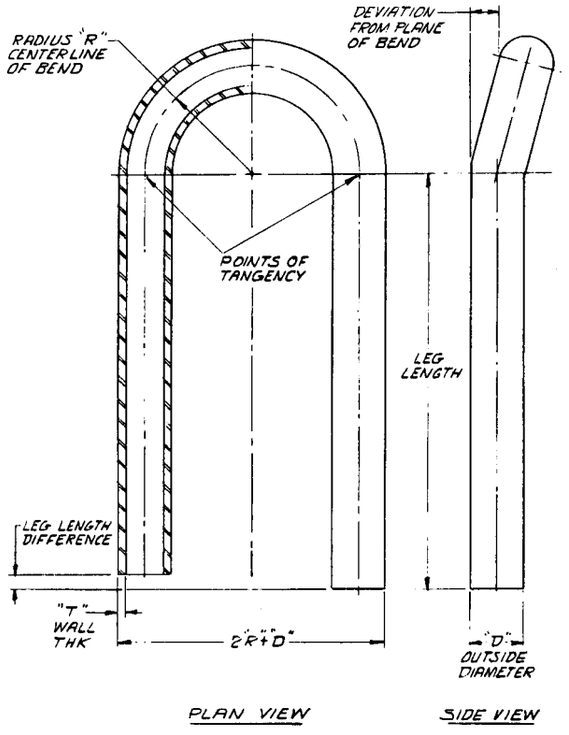


FIG. 1 PLANE BEND FOR U-TUBE

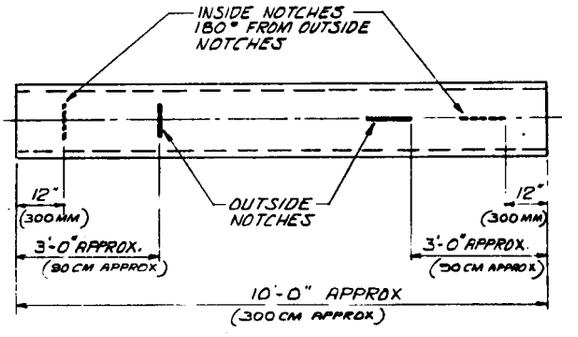


FIG. 2 EDDY-CURRENT TEST STANDARD

TABLE 1
CHEMICAL REQUIREMENTS

Grade	UNS S40900 TP409	UNS S43035 TP439	UNS S44627 TP XM-27	UNS S44626 TP XM-33	UNS S44635 25-4-4	UNS S44660 26-3-3	UNS S44700 29-4	UNS S44800 29-4-2	UNS S44400 18-2	UNS S44735 29-4C
Element	Composition, %									
C, max	0.08	0.07	0.01[B]	0.06	0.025	0.030	0.010	0.010	0.025	0.030
Mn, max	1.0	1.00	0.40	0.75	1.00	1.00	0.30	0.30	1.00	1.00
P, max	0.045	0.040	0.02	0.040	0.040	0.040	0.025	0.025	0.040	0.040
S, max	0.045	0.030	0.02	0.020	0.030	0.030	0.020	0.020	0.030	0.030
Si, max	1.00	1.00	0.40	0.75	0.75	1.00	0.20	0.20	1.00	1.00
Ni	0.50 max	0.50 max	0.5[C] max	0.50 max	3.5–4.5	1.00–3.50	0.15 max	2.0–2.5	1.00 max	1.00 max
Cr	10.50–11.75	17.00–19.00	25.0–27.5	25.0–27.0	24.5–26.0	25.0–28.0	28.0–30.0	28.0–30.0	17.5–19.5	28.0–30.0
Mo	. . .	. . .	0.75–1.50	0.75–1.00	3.5–4.5	3.0–4.0	3.5–4.2	3.5–4.2	1.75–2.50	3.60–4.20
Al	. . .	0.15 max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Cu	. . .	. . .	0.2 max	0.20 max	. . .	. . .	0.15 max	0.15 max	. . .	. . .
N	. . .	0.04 max	0.015 max	0.040 max	0.035	0.040 max	0.020 max[A]	0.020 max[A]	0.035 max	0.045 max
Ti	6 × C min; 0.75 max	0.20 + 4(C + N) min; 1.10 max	. . .	7 × (C + N) but no less than 0.20 min; 1.00 max	(Ti + Cb) = 0.2 + 4(C + N) min; 0.80 max	(Ti + Cb) = 6 × (C + N) but no less than 0.20 min; 1.00 max			(Ti + Cb) = 0.20 + 4(C + N) min; 0.80 max	(Ti + Cb) 6 × (C + N) but no less than 0.20 min; 1.00 max
Cb	. . .	. . .	0.05–0.20	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A] Carbon + nitrogen = 0.025 max.
[B] For small diameter or thin walls, or both, tubing, where many drawing passes are required, a carbon maximum of 0.015% is necessary. Small outside diameter tubes are defined as those less than 0.500 in [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.040 in. [1 mm] in minimum wall thickness).
[C] Nickel + copper.

TABLE 2
TENSILE REQUIREMENTS

Grade	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation[A] in 2 in. or 50 mm, min, %
TP 409	55 [380]	30 [205]	20
TP 439	60 [415]	30 [205]	20
TP XM-27	65 [450]	40 [275]	20
TP XM-33	68 [470]	45 [310]	20
25-4-4	90 [620]	75 [515]	20
26-3-3	85 [585]	65 [450]	20
29-4	80 [550]	60 [415]	20
29-4-2	80 [550]	60 [415]	20
18-2	60 [415]	35 [240]	20
29-4C	75 [515]	60 [415]	18

[A] For longitudinal strip tests, a deduction of 0.90% for 29-4C and 1% for all other grades shall be made from the basic minimum elongation for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm]. The following table gives the computed minimum values.

Wall Thickness		Elongation in 2 in. or 50 mm, min, %	
in.	mm	29-4C	All Other
$\frac{5}{16}$ (0.312)	8	18	20
$\frac{9}{32}$ (0.281)	7.2	17	19
$\frac{1}{4}$ (0.250)	6.4	16	18
$\frac{7}{32}$ (0.219)	5.6	15	17
$\frac{3}{16}$ (0.188)	4.8	14	16
$\frac{5}{32}$ (0.156)	4	13	15
$\frac{1}{8}$ (0.125)	3.2	13	14
$\frac{3}{32}$ (0.094)	2.4	12	13
$\frac{1}{16}$ (0.062)	1.6	11	12
0.062 to 0.035, excl	1.6 to 0.9	10	12
0.035 to 0.022, excl	0.9 to 0.6	10	11
0.022 to 0.015, excl	0.6 to 0.4	10	11

GENERAL NOTE: The above table gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

Grade	Equation[B]
29-4C	$E = 28.8t + 9.00$ [$E = 1.13t + 9.00$]
All other	$E = 32t + 10.00$ [$E = 1.25t + 10.00$]

where
E = elongation in 2 in. or 50 mm, %, and
t = actual thickness of specimen, in. [mm].

[B] Calculated elongation requirements shall be rounded to the nearest whole number.

TABLE 3
HARDNESS REQUIREMENTS

Grade	Brinell Hardness max	Rockwell Hardness, B Scale, max
TP 409	207	95
TP 439	207	95
TP XM-27	241	100
TP XM-33	241	100
25-4-4	270	27[A]
26-3-3	265	25[A]
29-4	241	100
29-4-2	241	100
18-2	217	95
29-4C	241	100

[A] Rockwell Hardness, C scale.

TABLE 4
TUBE LEG LENGTH TOLERANCE

Leg Length, ft [m]	Plus Tolerance, in. [mm]
Up to 20 [6], incl	1/8 [3.2]
Over 20 to 30 [6 to 9], incl	5/32 [4.0]
Over 30 to 40 [9 to 12], incl	3/16 [4.8]

TABLE 5
SQUARENESS OF ENDS TOLERANCE

Tube OD, in. [mm]	Tolerance, in. [mm]
Up to 5/8 [15.9], incl	0.010 [0.25]
Over 5/8 to 1 in. [15.9 to 25.4], incl	0.016 [0.41]

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order, in which event the necessary tests shall be made by the manufacturer prior to the bending or shipment of the tubing.

S1. Nondestructive Eddy-Current Test

S1.1 Each tube in the finished condition, except for bending if that is required, shall be tested by passing it through an electric nondestructive tester capable of detecting defects on the entire cross section of the tube. Suitable instrumentation shall be used to clearly distinguish the artificial defects. The outside and inside surfaces of the tubes shall be free of loose scale, metallic particles, or other material that would tend to restrict signals or create electrical noise. The tubing shall be inspected by feeding it longitudinally through an inspection coil or coils with a diameter suitable for the diameter of tubing to be inspected. The instrument calibration shall be accomplished with a reference standard prepared from the appropriate length of selected tubing of the same size, grade, and physical condition as the material to be inspected. The standard shall be fed through the coil at the same speed that the inspection of the tubing is performed.

S1.2 The factors listed in S1.3 shall be selected or adjusted, or both, in accordance with the instrument manufacturer's instructions, for the particular instrument involved as required to achieve optimum instrument distinction between the reference defects and plain portions of the tube.

S1.3 The following as well as other factors involved shall not be used in such a manner that they detract from the overall ability of the instrument to detect defects: test frequency, direct-current saturation level, filter networks, phase-analysis circuits, coil diameter, and instrument gain.

S1.4 The reference standard shall consist of a defect-free sample of the same size, alloy, and condition (temper) as that being tested, and shall contain longitudinal and circumferential notches on the outside diameter establishing the rejection level of the tubing to be tested. Inside diameter notches, both longitudinal and transverse, shall also be a part of the reference standard. These inside notches may be larger than the outside notches, and are intended for use only to assure instrument phase settings capable of yielding optimum inside surface sensitivity.

S1.4.1 All notches shall be produced by EDM methods. The outside diameter notches shall be of the dimensions shown in Table S1.1.

S1.5 All tubing shall meet this specification. The instrument calibration shall be verified at the start of testing, after any shut down of the test equipment, after any test equipment adjustment, or at least every ½ h of continuous production testing, or both. Tubes generating a signal above the outside-diameter calibration standard sensitivity level shall be rejected.

S1.6 Tubes may be reconditioned and retested provided reconditioning does not adversely effect the minimum wall thickness or other properties of the tube specification requirements. Upon agreement between purchaser and manufacturer, the referee method, employing ultrasonic testing, may be employed for retesting tubes rejected by the eddy-current test. The calibration standard for this test shall be identical to that required for the eddy-current test.

S2. Nondestructive Eddy-Current Testing (Select Commercial Grade)

S2.1 The manufacturer shall test the tubing using the procedure outlined in Supplementary Requirement S1, except for the notch standards, which shall be as indicated in Table S1.2.

S3. Report

S3.1 A report shall be furnished by the manufacturer to include a record of all tests performed to qualify material to this specification. This record shall include numbers of tests performed and qualitative or quantitative results as are applicable.

98

TABLE S1.1
NOTCH DEPTH

OD, in. [mm]	Wall, in. [mm]	Depth, in. [mm][A]	Length, max, in. [mm]	Width, max
5/8 to 1 [15.9 to 25.4] incl	0.028 [0.71] and heavier	0.005 [0.12] or 10.8% of specified average wall (when average wall is ordered), or 11.8% of specified minimum wall (when minimum wall is ordered), whichever is greater	0.375 [9.52]	wall thickness, but not greater than 0.062 in. [1.6 mm]

[A] The tolerance of notch depth shall be ±8% or ±0.0005 in. [0.01 mm], whichever is greater. Refer to Fig. 2 for notch location orientation and length of calibration standard.

98

TABLE S1.2
NOTCH DEPTH FOR SELECT COMMERCIAL GRADE

OD, in. [mm]	Wall, in. [mm]	Depth, in. [mm]	Length, max, in. [mm]	Width, max
5/8 to [15.9 to 25.4], incl	0.035 [0.9 mm] and heavier	0.005 [0.12] or 10.8% of specified average wall (when average wall is ordered), or 11.8% of specified minimum wall (when minimum wall is ordered), whichever is greater	0.375 [9.5]	3 times notch depth
5/8 to 1 [15.9 to 25.4], incl	less than 0.035 [0.9 mm]	0.005 [0.12] or 10.8% of specified average wall (when average wall is ordered), or 11.8% of specified minimum wall (when minimum wall is ordered), whichever is greater	0.375 [9.5]	wall thickness

SPECIFICATION FOR STEEL SHEET, HIGH-STRENGTH, LOW-ALLOY, HOT-ROLLED, FOR WELDED LAYERED PRESSURE VESSELS

SA-812/SA-812M

(Identical with ASTM Specification A 812/A 812M-96.) 98

1. Scope

1.1 This specification covers hot-rolled, high-strength, low-alloy steel sheet intended primarily for use in coil form in the construction of welded layered pressure vessels.

1.2 The following grades are included in this specification:

	Mechanical Requirements			
	Yield Strength, min		Tensile Strength, min	
Grade	ksi	MPa	ksi	MPa
65	65	450	85	585
80	80	550	100	690

1.3 This material is produced in coil form. However, testing is to represent the back end and the middle of the slab as rolled — see 6.1.4. The purchaser should therefore recognize this requires cutting the as-rolled coil to obtain test samples and results in half-size coils.

1.4 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standard. Within the text the SI units are shown in brackets. The values stated in each system are not exact equivalents, therefore each system must be used independently of the other. Combining values of the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 568/A 568M Specification for Steel, Sheet, Carbon and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

3. General Requirements for Delivery

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specifications A 568/A 568M unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information, as required, to describe the material adequately:

4.1.1 Specification number, grade, and date of issue,

4.1.2 Name of material (hot-rolled sheet),

4.1.3 Special requirements, if required, and

4.1.4 Dimensions, including type of edges.

4.1.4.1 As agreed upon between the purchaser and the producer, material ordered to this specification will be supplied to meet the appropriate standard or restricted thickness tolerance table shown in Specification A 568/A 568M.

NOTE 1 — Not all producers are capable of meeting all of the limitations of the thickness tolerance tables in Specification

A 568/A 568M. The purchaser should contact the producer regarding possible limitations prior to placing an order.

NOTE 2 — A typical ordering description is as follows: ASTM Axxx, Grade 65, Hot-Rolled Sheet, 0.157 in. [4.00 mm] by 48 in. [1220 mm] by coil, cut edges.

5. Chemical Requirements

5.1 *Cast or Heat Analysis* — The analysis of the steel shall conform to the requirements in Table 1.

6. Mechanical Property Requirements

6.1 *Tensile Strength:*

6.1.1 *Requirements* — Material as represented by the test specimen shall conform to the tensile requirements specified in Table 2.

6.1.2 *Number of Tests* — Two tensile tests shall be made from the product of each slab as rolled.

6.1.3 *Location and Orientation:*

6.1.3.1 Tensile test specimens shall be taken at locations representing the middle and back end of each slab as rolled.

6.1.3.2 Tensile test samples shall be taken from the full thickness of the sheet as rolled.

6.1.3.3 Tensile test specimens shall be taken from a location approximately halfway between the center of the sheet and the edge of the material as-rolled.

6.1.3.4 Tensile test specimens shall be taken with the axis of the test specimen perpendicular to the rolling direction (transverse test).

6.1.4 *Test Method* — Yield strength shall be determined by either the 0.2% offset method or by the 0.5% extension under load method unless otherwise specified.

7. Finish and Appearance

7.1 *Surface Finish* — Unless otherwise specified, the material shall be furnished without removing the hot-rolled oxide or scale.

7.2 *Edges* — Unless otherwise specified, mill edges shall be furnished.

8. Marking

8.1 The name or the brand of the manufacturer, heat number, slab or coil number, specification number and year of issue, and grade shall be legibly and durably marked on each finished coil. Steel-die marking of coils is prohibited.

9. Certification and Reports

9.1 The manufacturer shall furnish copies of a test report showing the results of the cast or heat analysis and mechanical property tests made to determine compliance with this specification. The report shall include the purchase order number, specification designation, and test identification number correlating the test results with material represented.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %	
	Grade 65, Heat or Cast	Grade 80, Heat or Cast
Carbon, max	0.23	0.23
Manganese, max	1.40	1.50
Phosphorus, max	0.035	0.035
Sulfur, max	0.040	0.040
Silicon	[A]	0.15–0.50
Columbium plus vanadium	0.02–0.15 [B]	0.02–0.15 [B]
Chromium, max	. . .	[C]

[A] Killed steel may be supplied when specified. When silicon-killed steel is ordered, a range from 0.15 to 0.50% shall be supplied.
[B] Columbium content not to exceed 0.05% on heat analysis, 0.06% on product analysis.
[C] Chromium may be present as an additional element but shall not exceed 0.35%.

TABLE 2
TENSILE REQUIREMENTS

	Grade 65	Grade 80
Tensile strength:		
ksi	85–110	100–125
MPa	585–760	690–860
Yield strength, min:[A]		
ksi	65	80
MPa	450	550
Elongation in 2 in. [50 mm], min, %:		
Under 0.230 to 0.145 in. [under 6.0 to 3.8 mm], incl. in thickness	15	13
Under 0.145 to 0.089 in. [under 3.8 to 2.2 mm], incl. in thickness	14	12
Under 0.089 to 0.057 in. [under 2.2 to 1.4 mm], incl. in thickness	13	11
Elongation in 8 in. [200 mm], min, %:		
Under 0.230 to 0.145 in. [under 6.0 to 3.8 mm], incl. in thickness	97	

[A] Yield strength determined by the 0.2% offset or 0.5% extension under load methods.

SPECIFICATION FOR SINGLE- OR DOUBLE-WELDED AUSTENITIC STAINLESS STEEL PIPE

SA-813/SA-813M

(Identical with ASTM Specification A 813/A 813M-95 except for clarified heat treatment requirements in 4.2.2.)

1. Scope

1.1 This specification covers two classes of fit-up and alignment quality straight-seam single- or double-welded austenitic steel pipe intended for high-temperature and general corrosive service.

NOTE 1 — When the impact test criterion for a low-temperature service would be 15 ft · lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades 304, 304L, and 347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3 for service at temperature as low as −425°F [−250°C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as −325°F [−200°C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10%, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than −50°F [−45°C].

1.2 Grades TP304H, TP304N, TP316H, TP316N, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP316, TP321, TP347, and TP348, and are intended for high-temperature service.

1.3 Two classes of pipe are covered as follows:

1.3.1 *Class SW* — Pipe, single-welded with no addition of filler metal and

1.3.2 *Class DW* — Pipe, double-welded with no addition of filler metal.

1.4 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.5 Table 1 lists the dimensions of welded stainless steel pipe as shown in ANSI B36.19. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of the specification.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
A 751 Test Methods, Practices, and Definitions for Chemical Analysis of Steel Products
E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings
E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ANSI Standards:*

B1.20.1 Pipe Threads, General Purpose
B36.10 Welded and Seamless Wrought Steel Pipe
B36.19 Stainless Steel Pipe

2.3 *ASME Boiler and Pressure Vessel Code:* Section VIII Division 1, Pressure Vessels

3. Ordering Information

3.1 Orders for material under this specification should include the following as required, to describe the desired material adequately:

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (austenitic steel pipe),

3.1.3 Class (1.3). If not specified by the purchaser, the producer shall have the option to furnish either single-welded (SW) or double-welded (DW) pipe,

3.1.4 Grade (Table 2),

3.1.5 Size (NPS or outside diameter and schedule number or average wall thickness),

3.1.6 Length (specific or random), (Section 9),

3.1.7 End finish (section on Ends of Specification A 530/A 530M),

3.1.8 Optional requirements (Section 8), (Supplementary Requirement S1 to S8),

3.1.9 Test report required (Section on Certification of Specification A 530/A 530M),

3.1.10 Specification number, and

3.1.11 Special requirements or exceptions to the specification.

4. Materials and Manufacture

4.1 *Manufacture:*

4.1.1 The pipe shall be made by a machine-welding or an automatic-welding process, welding from one or both sides and producing full penetration welds with no addition of filler metal in the welding operation.

4.1.2 Weld repairs, the addition of compatible filler metal, may be made to weld joint in accordance with the requirements of the section on Repair by Welding of Specification A 530/A 530M.

4.1.3 The pipe shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

4.2 *Heat Treatment:*

4.2.1 Except as provided in 4.2.5 and 4.2.6, all pipe shall be furnished in the heat-treated condition, except pipe sizes over NPS 6 may be furnished in the unheat-treated condition when specified in the order. When the pipe is furnished without final heat treatment, each pipe shall be marked HT-O and when a material test report for such pipe is furnished to the purchaser, the report shall indicate that the pipe has not been heat-treated. The heat-treatment procedure, except for H grades, N08367, and S31254, shall consist of heating the pipe to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means.

4.2.2 All H grades shall be furnished in the solution-treated condition. For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. If cold working is involved in processing, the minimum solution treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000°F [1100°C] and for Grades TP304H and TP316H, 1900°F [1040°C]. If the H Grade is hot rolled, the minimum solution treating temperatures for Grades TP321H, TP347H, and TP348H shall be 1925°F [1050°C], and for Grades TP304H and TP316H, 1900°F [1040°C].

4.2.3 The heat-treatment procedure for S31254 shall consist of heating the pipe to a minimum temperature of 2100°F [1150°C] and quenching in water or rapidly cooling by other means.

4.2.4 UNS N08367 should be solution annealed from 2025°F minimum followed by rapid quenching.

4.2.5 Except for H Grades and S31254, pipe sizes over NPS 6 may be furnished in the unheat-treated condition when specified in the order.

4.2.6 H Grades and S31254 in pipe sizes NPS 6 may be furnished in the unheat-treated condition when specified in the order, provided the heat treatment of 4.2.2 or 4.2.3, as applicable, is applied by the purchaser.

4.2.7 When the pipe is furnished without final heat treatment, each pipe shall be marked HT-O and when a material test report for such pipe is furnished to the purchaser, the report shall indicate that the pipe has not been heat-treated.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

6. Product Analysis

6.1 At the request of the purchaser, an analysis of one length of flat-rolled stock from each heat, or one pipe from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel.

NPS Number	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5 inclusive	200 or fraction thereof
6 and over	100 or fraction thereof

6.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 5.

6.3 If the analysis of one of the tests specified in 6.1 does not conform to the requirements specified in Section 5, an analysis of each length of flat-rolled stock from each heat or pipe from the same heat or lot may be made, and all pipe conforming to the requirements shall be accepted.

6.4 For referee purposes, Test Methods, Practices, and Terminology A 751 shall be used.

7. Tensile Requirements

7.1 The tensile properties of the material shall conform to the requirements prescribed in Table 3.

8. Permissible Variations in Dimensions

8.1 Permissible variations in dimensions shall not exceed the following at any point in each length of pipe.

8.1.1 *Specified Diameter* — The outside diameter shall be based on circumferential measurement and shall not exceed the tolerances stated as follows:

8.1.1.1 For sizes up to and including NPS 1¼, ±0.010 in. [±0.25 mm],

8.1.1.2 For sizes NPS 1½ up to and including NPS 6, ±0.020 in. [±0.5 mm],

8.1.1.3 For sizes NPS 8 up to and including NPS 18, ±0.030 in. [±0.75 mm],

8.1.1.4 For sizes NPS 20 up to and including NPS 24, ±0.040 in. [±1 mm], and

8.1.1.5 For sizes NPS 30, ±0.050 in. [±1.25 mm].

8.1.1.6 Outside diameter tolerances closer than shown above may be obtained by agreement between the pipe manufacturer and purchaser.

8.1.2 *Out-of-Roundness* — The difference between the major and the minor outside diameter shall not be more than 1.5% of the specified outside diameter.

8.1.3 *Alignment (Camber)* — Using a 10 ft [30 m] straightedge placed so that both ends are in contact with the pipe, the camber shall not be more than $^{3}/_{16}$ in. [4.8 mm].

8.1.4 *Thickness* — The wall thickness at any point in the pipe excluding the weld, shall not be more than 12% under or over the nominal thickness for wall thickness less than 0.188 in. [4.8 mm] and not more than 0.030 in. [0.8 mm] under or over the nominal thickness for wall thickness 0.188 in. [4.8 mm] and greater. Weld reinforcement not to exceed 20% of the wall thickness is permitted on each of the inside and outside surfaces of the pipe.

9. Lengths

9.1 Pipe lengths shall be in accordance with the following regular practice:

9.1.1 Unless otherwise agreed upon, all sizes up to and including NPS 8 are available in a length up to 24 ft (Note 2) with the permissible range of 15 to 24 ft (Note 2). Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

NOTE 2 — The value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric values(s) shall be agreed upon between the manufacturer and purchaser.

9.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and not more than ¼ in. [6 mm] over that specified.

10. Workmanship, Finish, and Appearance

10.1 The finished pipes shall be free of injurious imperfections and shall have a workmanlike finish. Minor imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted in Section 8.

11. Examination of Double-Welded Pipe

11.1 Both ends of each double-welded (Class DW) pipe shall be visually examined to determine that complete fusion was attained between the two welds. In lieu of examining the ends of the pipe, this examination may be performed on cropped ends removed from both ends of each double welded pipe.

12. Mechanical Tests Required

12.1 *Transverse or Longitudinal Tension Test* — One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes. Pipe size greater than NPS 6 shall be tested using the transverse tension test with the weld centered in the gage length of the test specimen. Test specimens shall be taken from the pipe or testplates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as prolongation of the pipe longitudinal weld seam.

NOTE 3 — The term lot, for mechanical tests, applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment: (1) in a continuous heat-treatment furnace, or (2) in a batch-type heat-treatment furnace, equipped with recording pyrometers and automatically controlled within a 50°F [30°C] range, the larger of: (a) each 200 ft [60 m] or fraction thereof or (b) that pipe heat treated in the same batch furnace charge.

12.2 *Flattening Test* — For material heat treated in a batch-type furnace, flattening tests shall be made on 5% of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall be made on a sufficient number of pipe to constitute 5% of the lot, but in no case less than two lengths of pipe.

12.2.1 For pipe where the diameter equals or exceeds NPS 10, a transverse instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5% of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

12.3 *Hydrostatic Test* — Each length of finished pipe shall be subjected to the hydrostatic test in accordance with Specification A 530/A 530M, except when specified in the order, the pipe may be furnished without hydrostatic test and each length of pipe shall be marked NH.

13. Product Marking

13.1 In addition to that specified in Specification A 530/A 530M, the marking shall include the manufacturer's private identifying mark and identified as either single welded (SW) or double welded (DW) as applicable. For Grades TP304H, TP316H, TP321H, TP347H, and TP348H, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weights.

13.2 When heat treatment of the pipe is not performed, the pipe shall be marked HT-O.

13.3 When a hydrostatic test of the pipe is not performed, the pipe shall be marked NH.

14. General Requirements

14.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

TABLE 1
DIMENSIONS OF WELDED AND SEAMLESS STAINLESS STEEL PIPE[A] (ANSI B36.19-1965)

NOTE 1 — Table 1 is based on Table 1 of the American National Standard for Stainless Steel Pipe (ANSI B36.19-1965).
NOTE 2 — The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[B]		Schedule 10S[B]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
1/8	0.405	10.29	...	...	0.049[C]	1.24	0.068	1.73	0.095	2.41
1/4	0.540	13.72	...	...	0.065[C]	1.65	0.088	2.24	0.119	3.02
3/8	0.675	17.15	...	...	0.065[C]	1.65	0.091	2.31	0.126	3.20
1/2	0.840	21.34	0.065[C]	1.65	0.083[C]	2.11	0.109	2.77	0.147	3.73
3/4	1.050	26.67	0.065[C]	1.65	0.083[C]	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065[C]	1.65	0.109[C]	2.77	0.133	3.38	0.179	4.55
1 1/4	1.660	42.16	0.065[C]	1.65	0.109[C]	2.77	0.140	3.56	0.191	4.85
1 1/2	1.900	48.26	0.065[C]	1.65	0.109[C]	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065[C]	1.65	0.109[C]	2.77	0.154	3.91	0.218	5.54
2 1/2	2.875	73.03	0.083	2.11	0.120[C]	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120[C]	3.05	0.216	5.49	0.300	7.62
3 1/2	4.000	101.60	0.083	2.11	0.120[C]	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120[C]	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109[C]	2.77	0.134[C]	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134[C]	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109[C]	2.77	0.148[C]	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134[C]	3.40	0.165[C]	4.19	0.365	9.27	0.500[C]	12.70[C]
12	12.750	323.85	0.156[C]	3.96	0.180[C]	4.57	0.375[C]	9.52[C]	0.500[C]	12.70[C]
14	14.000	355.60	0.156[C]	3.96	0.188	4.78	...	...	...	...
16	16.000	406.40	0.165[C]	4.19	0.188	4.78	...	...	...	...
18	18.000	457.20	0.165[C]	4.19	0.188	4.78	...	...	...	...
20	20.000	508.00	0.188[C]	4.78	0.218[C]	5.54	...	...	...	...
22	22.000	558.80	0.188[C]	4.78	0.218[C]	5.54	...	...	...	...
24	24.000	609.60	0.218[C]	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

[A] For pipe sizes not listed, the dimensions and tolerances shall be by agreement between the purchaser and producer.
[B] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).
[C] These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10-1979).

TABLE 2
CHEMICAL REQUIREMENTS

Grade	UNS Designation[A]	Composition, %														
		Carbon, max[B]	Manganese, max[B]	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium plus Tantalum	Tantalum, max	Nitrogen[C]	Vanadium	Copper	Cerium
TP304	S30400	0.08	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	...	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	...	...	...	...
TP304L	S30403	0.035[D]	2.00	0.045	0.030	0.75 max	8.00–13.0	18.0–20.0	...	...	...	...	...	...	...	...
TP304N	S30451	0.08	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...	...	...
TP304LN	S30453	0.035	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	0.75 max	12.00–16.00	22.00–24.00	0.75 max	...	10 × C min, 1.10 max	...	...	...	0.75 max	...
TP309S	S30908	0.08	2.00	0.045	0.030	0.75 max	12.00–15.00	22.00–24.00	0.75 max	...	...	...	...	...	0.75 max	...
TP310Cb	S31040	0.08	2.00	0.045	0.030	0.75 max	19.00–22.00	24.00–26.00	0.75 max	...	10 × C min, 1.10 max	...	...	...	0.75 max	...
TP310S	S31008	0.08	2.00	0.045	0.030	0.75 max	19.00–22.00	24.00–26.00	0.75 max	...	...	...	...	...	0.75 max	...
TP316	S31600	0.08	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...
TP316L	S31603	0.035[D]	2.00	0.045	0.030	0.75 max	10.0–15.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...
TP316N	S31651	0.08	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.00–3.00				0.10–0.16	...	...	...
TP316LN	S31653	0.035	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...	...	...
TP317	S31700	0.08	2.00	0.045	0.030	0.75 max	11.0–14.0	18.0–20.0	3.00–4.00	...	...	...	...	...	...	...
TP317L	S31703	0.035	2.00	0.045	0.030	0.75 max	11.0–15.0	18.0–20.0	3.00–4.00	...	...	...	...	...	...	...
TP321	S32100	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	[E]	...	...	...	...	...	...
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	[F]	...	...	...	...	...	...
TP347	S34700	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[G]	...	...	...	...	...
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[H]	...	...	...	...	...
TP348	S34800	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[G]	0.10	...	...	...	...
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[H]	0.10	...	...	...	...
TPXM-10	S21900	0.08	8.00–10.00	0.040	0.030	1.00 max	5.50–7.50	19.00–21.50	...	...	...	...	0.15–0.40	...	...	...
TPXM-11	S21903	0.04	8.00–10.00	0.040	0.030	1.00 max	5.50–7.50	19.00–21.50	...	...	...	...	0.15–0.40	...	...	...
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.50–18.50	17.0–19.0	...	...	...	...	...	...	...	...
TPXM-19	S20910	0.060	4.00–6.00	0.040	0.030	1.00 max	11.50–13.50	20.50–23.50	1.50–3.00	...	0.10–0.30	...	0.20–0.40	0.10–0.30	...	...
TPXM-29	S24000	0.080	11.50–14.50	0.060	0.030	1.00 max	2.25–3.75	17.0–19.0	...	...	...	...	0.20–0.40	...	...	...
...	S31254	0.020	1.00	0.030	0.010	0.80 max	17.50–18.50	19.50–20.50	6.00–6.50	...	...	...	0.180–0.220	...	0.50–1.00	...
...	S30815	0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	...	...	...	...	0.14–0.20	...	...	0.03–0.08
...	N08367	0.030	2.00	0.040	0.030	1.00 max	23.50–25.50	20.00–22.00	6.00–7.00	...	...	...	0.18–0.25	...	0.75 max	...

[A] New designation established in accordance with ASTM E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

[B] Maximum, unless otherwise indicated.

[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

[D] For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040% is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.044 in. [1 mm] in minimum wall thickness).

[E] The titanium content shall be not less than five times the carbon content and not more than 0.70%.

[F] The titanium content shall be not less than four times the carbon content and not more than 0.60%.

[G] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.00%.

[H] The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.0%.

TABLE 3
TENSILE REQUIREMENTS

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
TP304L	S30403	70 [485]	25 [170]
TP316L	S31603	70 [485]	25 [170]
TP304	S30400	75 [515]	30 [205]
TP304H	S30409	75 [515]	30 [205]
TP309Cb	S30940	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP316	S31600	75 [515]	30 [205]
TP316H	S31609	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
TP321	S32100	75 [515]	30 [205]
TP321H	S32109	75 [515]	30 [205]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21903	90 [620]	50 [345]
TPXM-15	S31800	75 [515]	30 [205]
TPXM-29	S24000	100 [690]	55 [380]
TPXM-19	S20910	100 [690]	55 [380]
TP304N	S30451	80 [550]	35 [240]
TP316N	S31651	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
TP316LN	S31653	75 [515]	30 [205]
. . .	S31254	94 [650]	44 [300]
. . .	S30815	87 [600]	45 [310]
. . .	N08367		
	$t \le 0.187$	100 [690]	45 [310]
	$t > 0.187$	95 [655]	45 [310]

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipes NPS 5 and larger in nominal size, there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5, there shall be one product analysis made from ten lengths per heat of steel or from 10% of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 5 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10% of the lengths furnished per heat of steel. This applies only to pipe NPS 8 and larger in nominal size.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be tested, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross direction from one end or both ends of each pipe and shall show sound welds and reasonably uniform material free of injurious laminations, cracks, and similar objectionable imperfections. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable imperfections, the length shall be rejected subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Eddy Current Examination

S5.1 Pipe soundness shall be determined through eddy-current examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S6. Ultrasonic Examination

S6.1 Pipe soundness shall be determined through ultrasonic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S7. Radiographic Examination

S7.1 Weld soundness shall be determined through radiographic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S8. Corrosion Requirements

S8.1 *Boiling Nitric Acid Test* — Except for Grade TP 321, coupons representing finished pipe made of nonmolybdenum-bearing material (0.50% and less molybdenum) shall meet the requirements of Practice C of Practices A 262. The condition of the test specimens and the corrosion rates are as follows: Types 304L, 304LN, 347, and 348 shall be tested in the sensitized condition (heated for 1 h at 1240°F [670°C]) and the rate of penetration when the solution is tested in accordance with Practice C shall not exceed 0.0020 in. [0.05 mm] per month. All other nonmolybdenum-bearing types, except for Grade TP 321, shown in Table 2, shall be tested in the annealed and unsensitized condition and the rate of penetration shall not exceed 0.0015 in. [0.038 mm] per month.

S8.2 *Acidified Copper Sulfate Test* — Coupons representing finished pipe made of molybdenum-bearing material (over 0.50% molybdenum) and Type 321 shall meet the requirements of Practice E of Practices A 262. The condition of the test specimen is as follows: Types 316L, 316LN, 317L, and 321 shall be tested in the sensitized condition (heated for 1 h at 1240°F [670°C]). All molybdenum-bearing types shown in Table 2 shall be tested in the annealed and unsensitized condition. All specimens shall meet the requirements of the prescribed bend tests.

SPECIFICATION FOR COLD-WORKED WELDED AUSTENITIC STAINLESS STEEL PIPE

SA-814/SA-814M

(Identical with ASTM Specification A 814/A 814M-96 except for clarified heat treatment requirements in 5.2.2.) 98

1. Scope

1.1 This specification covers two classes of flanged and cold-bending quality cold-worked straight-seam single or double welded austenitic steel pipe intended for high-temperature and general corrosive services.

NOTE 1 — When the impact test criterion for a low-temperature service would be 15 ft · lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades 304, 304L, and 347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3 for service at temperature as low as −425°F [−250°C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as −325°F [−200°C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10%, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than −50°F [−45°C].

1.2 Grades TP304H, TP304N, TP316H, TP316N, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP316, TP321, TP347, and TP348, and are intended for high-temperature service.

1.3 Two classes of pipe are covered as follows:

1.3.1 *Class SW* — Pipe, single-welded with no addition of filler metal and

1.3.2 *Class DW* — Pipe, double-welded with no addition of filler metal.

1.4 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.5 Table 1 lists the dimensions of cold-worked single- or double-welded stainless steel pipe. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 751 Test Methods, Practices, and Definitions for Chemical Analysis of Steel Products

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ANSI Standards:*

B1.20.1 Pipe Threads, General Purpose

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *ASME Boiler and Pressure Vessel Code:* Section VIII Division 1, Pressure Vessels

3. General Requirements

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

4. Ordering Information

4.1 Orders for material under this specification should include the following as required, to describe the desired material adequately:

4.1.1 Quantity (feet, centimeters, or number of lengths),

4.1.2 Name of material (austenitic steel pipe),

4.1.3 Class (1.3). If not specified by the purchaser, the producer shall have the option to furnish either single-welded (SW) or double-welded (DW) pipe,

4.1.4 Grade (Table 2),

4.1.5 Size (NPS or outside diameter and schedule number or average wall thickness),

98 **4.1.6** Length (specific or random), (Section 10),

4.1.7 End finish (Section on Ends of Specification A 530/A 530M),

4.1.8 Optional requirements (Section 9), (Supplementary Requirements S1 to S8),

4.1.9 Test report required (Section on Certification of Specification A 530/A 530M),

4.1.10 Specification designation, and

4.1.11 Special requirements or exceptions to the specification.

5. Materials and Manufacture

5.1 *Manufacture:*

5.1.1 The pipe shall be made by a machine-welding or an automatic-welding process, welding from one or both sides and producing full penetration welds with no addition of filler metal in the welding operation.

5.1.2 Weld repairs, the addition of compatible filler metal, may be made to the weld joint in accordance with the requirements of the section on Repair by Welding of Specification A 530/A 530M.

5.1.3 Prior to final heat treatment of the pipe, the weld bead must be cold-worked by methods such as forging, planishing, drawing, swaging or bead rolling so as to obtain a flush condition on the inside and outside of the pipe. Undercuts shall be limited to shallow rounded depressions of less than 0.005 in. [0.127 mm] deep on either the inside or outside surface of the pipe with no encroachment of the minimum permitted wall thickness.

5.1.4 The pipe shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

5.2 *Heat Treatment:*

5.2.1 All pipe shall be furnished in the heat-treated condition. The heat-treatment procedure, except for H grades, N08367 and S31254, shall consist of heating the pipe to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means.

5.2.2 All H grades shall be furnished in the solution-treated condition. For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. The minimum solution treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000°F [1100°C] and for Grades TP304H and TP316H, 1900°F [1040°C].

5.2.3 The heat-treatment procedure for S31254 shall consist of heating the pipe to a minimum temperature of 2100°F [1150°C] and quenching in water or rapidly cooling by other means.

5.2.4 UNS N08367 should be solution annealed from 2025°F minimum followed by rapid quenching. 98

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

7. Product Analysis

7.1 At the request of the purchaser, an analysis of one length of flat-rolled stock from each heat, or one pipe from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number

of lengths of the same size and wall thickness from any one heat of steel:

NPS Number	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5 inclusive	200 or fraction thereof
6 and over	100 or fraction thereof

7.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 6.

7.3 If the analysis of one of the tests specified in 7.1 does not conform to the requirements specified in Section 6, an analysis of each length of flat-rolled stock from each heat or pipe from the same heat or lot may be made, and all pipe conforming to the requirements shall be accepted.

7.4 For referee purposes, Test Methods and Practices and Terminology of A 751 shall be used.

8. Tensile Requirements

8.1 The tensile properties of the material shall conform to the requirements prescribed in Table 3.

9. Permissible Variations in Dimensions

9.1 *Specified Diameter* — The diameter at any point in each length of pipe shall be within the tolerance specified in Table 1.

9.2 *Alignment (Camber)* — Using a 3 ft [1.0 m] straightedge placed so that both ends are in contact with the pipe, the camber shall not be more than 0.030 in. [0.8 mm].

9.3 *Thickness* — The wall thickness at any point in the pipe shall be within the thickness tolerance specified in Table 3, except that for pipe in which the wall thickness exceeds 0.188 in. [4.8 mm] a weld reinforcement of up to 0.015 in. [3.8 mm] is permitted on the inside of the pipe.

10. Lengths

10.1 Pipe lengths shall be in accordance with the following regular practice.

10.1.1 Unless otherwise agreed upon, all sizes up to and including NPS 4 are available in a length up to 24 ft (Note 2) with the permissible range of 15 to 24 ft (Note 2).

NOTE 2 — The value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric values(s) shall be agreed upon between the manufacturer and purchaser.

10.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and not more than $\frac{1}{4}$ in. [6 mm] over that specified.

10.1.3 No jointers are permitted unless otherwise specified.

11. Workmanship, Finish, and Appearance

11.1 The finished pipes shall be free of injurious imperfections and shall have a workmanlike finish. Minor imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted in Section 9.

12. Examination of Double-Welded Pipe

12.1 Both ends of each double-welded (Class DW) pipe shall be visually examined to determine that complete fusion was attained between the two welds. In lieu of examining the ends of the pipe, this examination may be performed on cropped ends removed from both ends of each double welded pipe.

13. Mechanical Tests Required

13.1 *Transverse or Longitudinal Tension Test* — One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes.

NOTE 3 — The term "lot", for mechanical tests, applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment (1) in a continuous heat-treatment furnace, or (2) in a batch-type heat-treatment furnace, equipped with recording pyrometers and automatically controlled within a 50°F [30°C] range, the larger of (a) Each 200 ft [60 m] or fraction thereof or, (b) That pipe heat treated in the same batch furnace charge.

13.2 *Flattening Test* — For material heat treated in a batch-type furnace, flattening tests shall be made on 5% of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall

be made on a sufficient number of pipe to constitute 5% of the lot, but in no case less than two lengths of pipe.

13.2.1 For pipe where the diameter equals or exceeds NPS 10, a transverse instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5% of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

13.3 *Hydrostatic Test* — Each length of finished pipe shall be subjected to the hydrostatic test in accordance with Specification A 530/A 530M.

14. Product Marking

14.1 In addition to that specified in Specification A 530/A 530M, the marking shall include the manufacturer's identifying mark and double-welded pipe shall be identified with the mark (DW). For Grades TP304H, TP316H, TP321H, TP347H, TP348H, and S30815, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

TABLE 1
PIPE DIMENSIONS[A]

NOTE — For pipe sizes not listed and for pipe ordered to the "M" designation of this specification, the dimensions and tolerances shall be by agreement between the purchaser and producer.

NPS No.	Outside Diameter	Outside Diameter Tolerance	Schedule	Wall	
				Thickness	Tolerance
1/8	0.405	+0.004	10	0.049	±0.004
		−0.002	40	0.068	±0.005
			80	0.095	±0.006
1/4	0.540	+0.005	10	0.065	±0.005
		−0.003	40	0.088	±0.006
			80	0.119	±0.009
3/8	0.675	+0.006	10	0.065	±0.005
		−0.004	40	0.091	±0.006
			80	0.126	±0.010
1/2	0.840	+0.007	5	0.065	±0.005
		−0.005	10	0.083	±0.006
			40	0.109	±0.009
			80	0.147	±0.011
3/4	1.060	+0.010	5	0.065	±0.005
		−0.007	10	0.083	±0.006
			40	0.113	±0.009
			80	0.154	±0.011
1	1.315	+0.010	5	0.065	±0.005
		−0.007	10	0.109	±0.009
			40	0.133	±0.011
			80	0.179	±0.014
1 1/4	1.660	+0.012	5	0.065	±0.005
		−0.008	10	0.109	±0.009
			40	0.140	±0.011
			80	0.191	±0.014
1 1/2	1.900	+0.015	5	0.065	±0.005
		−0.008	10	0.109	±0.009
			40	0.145	±0.011
			80	0.200	±0.015
2	2.375	+0.018	5	0.065	±0.005
		−0.008	10	0.109	±0.009
			40	0.154	±0.011
			80	0.218	±0.015
2 1/2	2.875	+0.020	5	0.065	±0.005
		−0.009	10	0.120	±0.010
			40	0.203	±0.015
			80	0.276	±0.020
3	3.500	+0.025	5	0.083	±0.006
		−0.010	10	0.120	±0.010
			40	0.216	±0.015
			80	0.300	±0.020
3 1/2	4.000	+0.025	5	0.083	±0.006
		−0.010	10	0.120	±0.010
			40	0.226	±0.018
			80	0.318	±0.020
4	4.500	+0.025	5	0.083	±0.006
		−0.010	10	0.120	±0.010
			40	0.237	±0.019
			80	0.337	±0.020

[A] All dimensions in inches.

TABLE 2
CHEMICAL REQUIREMENTS

Grade	UNS Designation[A]	Composition, %														
		Carbon, max[H]	Manganese, max[H]	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium plus Tantalum	Tantalum, max	Nitrogen[G]	Vanadium	Copper	Cerium
TP304	S30400	0.08	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	...	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	...	...	...	...
TP304L	S30403	0.035[B]	2.00	0.045	0.030	0.75 max	8.00–13.0	18.0–20.0	...	...	...	...	...	...	...	...
TP304N	S30451	0.08	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...	...	...
TP304LN	S30453	0.035	2.00	0.045	0.030	0.75 max	8.00–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	0.75 max	12.00–16.00	22.00–24.00	0.75 max	...	10 × C min, 1.10 max	...	...	...	0.75 max	...
TP309S	S30908	0.08	2.00	0.045	0.030	0.75 max	12.00–15.00	22.00–24.00	0.75 max	...	...	...	...	...	0.75 max	...
TP310Cb	S31040	0.08	2.00	0.045	0.030	0.75 max	19.00–22.00	24.00–26.00	0.75 max	...	10 × C min, 1.10 max	...	...	...	0.75 max	...
TP310S	S31008	0.08	2.00	0.045	0.030	0.75 max	19.00–22.00	24.00–26.00	0.75 max	...	...	...	...	...	0.75 max	...
TP316	S31600	0.08	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...
TP316L	S31603	0.035[B]	2.00	0.045	0.030	0.75 max	10.0–15.0	16.0–18.0	2.00–3.00	...	...	...	...	...	...	...
TP316N	S31651	0.08	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.00–3.00				0.10–0.16	...	...	...
TP316LN	S31653	0.035	2.00	0.045	0.030	0.75 max	10.0–14.0	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...	...	...
TP317	S31700	0.08	2.00	0.045	0.030	0.75 max	11.0–14.0	18.0–20.0	3.00–4.00	...	...	...	...	...	...	...
TP317L	S31703	0.035	2.00	0.045	0.030	0.75 max	11.0–15.0	18.0–20.0	3.00–4.00	...	...	...	...	...	...	...
TP321	S32100	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	[C]	...	...	...	...	...	...
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	[D]	...	...	...	...	...	...
TP347	S34700	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[E]	...	...	...	...	...
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[F]	...	...	...	...	...
TP348	S34800	0.08	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[E]	0.10	...	...	...	...
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	0.75 max	9.00–13.0	17.0–20.0	...	...	[F]	0.10	...	...	...	...
TPXM-10	S21900	0.08	8.00–10.00	0.040	0.030	1.00 max	5.50–7.50	19.00–21.50	...	...	...	...	0.15–0.40	...	...	...
TPXM-11	S21903	0.04	8.00–10.00	0.040	0.030	1.00 max	5.50–7.50	19.00–21.50	...	...	...	...	0.15–0.40	...	...	...
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.50–18.50	17.0–19.0	...	...	...	...	...	...	...	...
TPXM-19	S20910	0.060	4.00–6.00	0.040	0.030	1.00 max	11.50–13.50	20.50–23.50	1.50–3.00	...	0.10–0.30	...	0.20–0.40	0.10–0.30	...	...
TPXM-29	S24000	0.080	11.50–14.50	0.060	0.030	1.00 max	2.25–3.75	17.0–19.0	...	...	...	...	0.20–0.40	...	...	...
...	S31254	0.020	1.00	0.030	0.010	0.80 max	17.50–18.50	19.50–20.50	6.00–6.50	...	...	...	0.180–0.220	...	0.50–1.00	...
...	S30815	0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	...	...	...	...	0.14–0.20	...	...	0.03–0.08
...	N08367	0.030	2.00	0.040	0.030	1.00 max	23.50–25.50	20.00–22.00	6.00–7.00	...	...	...	0.18–0.25	...	0.75 max	...

[A] New designation established in accordance with ASTM E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

[B] For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040% is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.044 in. [1 mm] in minimum wall thickness).

[C] The titanium content shall be not less than five times the carbon content and not more than 0.70%.

[D] The titanium content shall be not less than four times the carbon content and not more than 0.60%.

[E] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.00%.

[F] The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.0%.

[G] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

[H] Maximum, unless otherwise indicated.

98

TABLE 3
TENSILE REQUIREMENTS

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
TP304L	S30403	70 [485]	25 [170]
TP316L	S31603	70 [485]	25 [170]
TP304	S30400	75 [515]	30 [205]
TP304H	S30409	75 [515]	30 [205]
TP309Cb	S30940	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP316	S31600	75 [515]	30 [205]
TP316H	S31609	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
TP321	S32100	75 [515]	30 [205]
TP321H	S32109	75 [515]	30 [205]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21903	90 [620]	50 [345]
TPXM-15	S31800	75 [515]	30 [205]
TPXM-29	S24000	100 [690]	55 [380]
TPXM-19	S20910	100 [690]	55 [380]
TP304N	S30451	80 [550]	35 [240]
TP316N	S31651	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
TP316LN	S31653	75 [515]	30 [205]
. . .	S31254	94 [650]	44 [300]
. . .	S30815	87 [600]	45 [310]
. . .	N08367		
	$t \le 0.187$	100 [690]	45 [310]
	$t > 0.187$	95 [655]	45 [310]

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipes NPS 5 and larger in nominal size, there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5, there shall be one product analysis made from ten lengths per heat of steel or from 10% of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 6 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10% of the lengths furnished per heat of steel. This applies only to pipe NPS 8 and larger in nominal size.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross direction from one end or both ends of each pipe and shall show sound welds and reasonably uniform material free of injurious laminations, cracks, and similar objectionable imperfections. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable imperfections, the length shall be rejected subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Eddy Current Examination

S5.1 Pipe soundness shall be determined through eddy-current examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S6. Ultrasonic Examination

S6.1 Pipe soundness shall be determined through ultrasonic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S7. Corrosion Requirements

S7.1 *Boiling Nitric Acid Test* — Except for Grade TP 321, coupons representing finished pipe made of nonmolybdenum-bearing material (0.50% and less molybdenum) shall meet the requirements Practice C of Practices A 262. The condition of the test specimen and the corrosion rates are as follows: Types 304L, 304LN, 347, and Type 348 shall be tested in the sensitized condition (heated for 1 h at 1240°F [670°C])

and the rate of penetration shall not exceed 0.0020 in. [0.05 mm]/month. All other nonmolybdenum-bearing types, except for Grade TP 321, shown in Table 2 shall be tested in the annealed and unsensitized condition and the rate of penetration when solution tested in accordance with Practice C shall not exceed 0.0015 in./month [0.038 mm/month].

S7.2 *Acidified Copper Sulfate Test* — Coupons representing finished pipe made of molybdenum-bearing material (over 0.50% molybdenum) and Type 321 shall meet the requirements of Practice E of Practices A 262. The condition of the test specimen is as follows: Types 316L, 316L, 317LN, 317L and 321 shall be tested in the sensitized condition (heated for 1 h at 1240°F [670°C]). All molybdenum-bearing types shown in Table 2 shall be tested in the annealed and unsensitized condition. All specimens shall meet the requirements of the prescribed bend tests.

S8. Flange Test

S8.1 A section of pipe shall be capable of having a flange turned over at a right angle to the body of the pipe without cracking. The width of the flange shall be not less than 15% of the outside diameter of the pipe.

SPECIFICATION FOR WROUGHT FERRITIC, FERRITIC/AUSTENITIC, AND MARTENSITIC STAINLESS STEEL PIPING FITTINGS

SA-815/SA-815M

(Identical with ASTM Specification A 815/A 815M-96^{E1})

A99

1. Scope

1.1 This specification covers two general classes, WP and CR, of wrought ferritic, ferritic/austenitic, and martensitic stainless steel fittings of seamless and welded construction covered by the latest revision of ANSI B16.9, ANSI B16.11, ANSI B16.28, MSS Standard Practice SP-79 and MSS Standard Practice SP-43. Fittings differing from these standards may be furnished in accordance with Supplementary Requirement S8.

1.1.1 Class WP fittings are subdivided into three sub-classes: Classes WP-S, WP-W, and WP-WX. They are manufactured to the requirements of ANSI B16.9, B16.11, B16.28; or MSS Standard Practice SP-79 and they shall have pressure ratings compatible with 12.2. Class WP-S fittings are those manufactured from seamless product by a seamless method of manufacture (marked with class symbol WP-S); Class WP-W fittings are those which contain welds where the fitting fabrication or construction welds have been radiographed (marked with class symbol WP-W); and Class WP-WX fittings are those which contain welds where all welds have been radiographed (marked with class symbol WP-WX).

1.1.2 Class CR fittings are those manufactured to the requirements of MSS SP-43, and they shall have pressure ratings compatible with 12.3.

1.2 This specification does not apply to cast fittings.

1.3 Optional supplementary requirements are provided. When desired, one or more of these may be specified in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

E 165 Test Method for Liquid Penetrant Inspection

2.2 *ANSI Standards:*

B16.9 Wrought Steel Butt-Welding Fittings

B16.11 Forged Steel Fittings, Socket-Welding and Threaded

B16.28 Wrought Steel Butt-Welding Short Radius Elbows and Returns

2.3 *MSS Standards:*

SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions

SP-43 Standard Practice for Light Weight Stainless Steel Butt-Welding Fittings

SP-79 Socket-Welding Reducer Inserts

2.4 *ASME Boiler and Pressure Vessel Codes:*

Section VIII Division I, Pressure Vessels

Section IX Welding Qualifications

2.5 *ASNT Standard:*

SNT-TC-1A(1984) Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Ordering Information

3.1 Orders for fittings under this specification shall include the following information:

3.1.1 Quantity, number of fittings of each kind,

3.1.2 Description of fitting and nominal dimension (standard or special),

3.1.3 Steel composition by grade designation,

3.1.4 Class WP or CR shall be specified. Class WP fittings may be further defined by specifying Class WP-S, WP-W or WP-WX,

3.1.4.1 Unless Class WP-S, WP-W, or WP-WX is specified by the purchaser, any may be furnished at the option of the supplier,

3.1.4.2 Class CR fittings shall not be substituted for fittings ordered to Class WP, but Class WP may be substituted for Class CR,

3.1.5 Additional requirements, if any (see 17.5), and

3.1.6 Supplementary requirements if any.

4. Materials

4.1 The material for fittings shall consist of forgings, bars, plates, or seamless or welded tubular products that conform to the chemical requirements in Table 1.

4.2 The steel shall be melted by one of the following processes:

4.2.1 Electric furnace (with separate degassing and refining optional),

4.2.2 Vacuum furnace, or

4.2.3 Electric furnace followed by vacuum or electroslag-consumable remelting.

4.3 If secondary melting is employed, the heat shall be defined as all ingots remelted from a primary heat.

5. Manufacture

5.1 *Forming* — Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining or by combination of two or more of these operations. The forming procedure shall be so applied that it will not produce surface discontinuities deeper than 5% of the specified nominal thickness of the fitting.

5.2 All classes of fittings shall be heat treated in accordance with Section 6.

5.3 Fittings ordered as Class WP-S shall be of seamless construction and shall meet all requirements of ANSI B16.9, B16.11, B16.28 or MSS SP-79.

5.4 Fittings ordered as Class WP-W shall meet the requirements of ANSI B16.9 or B16.28 and (*1*) shall have all welds made by the fitting manufacturer and all pipe welds made with the addition of filler metal radiographically examined throughout the entire length in accordance with Paragraph UW-51 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code; and (*2*) shall not require radiography of the starting pipe weld if the pipe was welded without the addition of filler metal.

5.5 Fittings ordered as Class WP-WX shall meet the requirements of ANSI B16.9 or B16.28 and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, radiographically examined throughout their entire length in accordance with Paragraph UW-51 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code. The radiography of welds for this class of fittings can be done either prior to or after forming at the option of the manufacturer.

5.6 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

5.7 Fittings covered in MSS SP-43 and ordered as CR shall meet the requirements of MSS SP-43 and do not require radiography.

5.8 All classes of fittings shall have the welders, welding operators, and welded procedures qualified under the provisions of Section IX of the ASME Boiler

and Pressure Vessel Code except that starting pipe welds made without the addition of filler metal do not require such qualification.

5.9 All joints welded with filler metal shall be finished in accordance with the requirements of Paragraph UW-35(a) of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code.

5.10 Fittings machined from bar shall be restricted to NPS 4 or smaller.

5.10.1 All caps machined from bar shall be examined by liquid penetrant in accordance with Practice E 165.

6. Heat Treatment

6.1 *Ferritic Grades* — As a final heat treatment, the ferritic fittings shall be reheated to a temperature of 1200°F [650°C] or higher, and cooled (as appropriate for the grade) to meet the requirements of this specification.

6.2 *Ferritic/Austenitic:*

6.2.1 As a final heat treatment, the ferritic/austenitic grade UNS S31803, shall be reheated to a temperature of 1870° to 2010°F [1020° to 1100°C], with subsequent quenching in water or rapidly cooling by other means.

6.2.2 As a final heat treatment, the ferritic/austenitic grade UNS S32750, shall be reheated to a temperature of 1920° to 2060°F [1025° to 1125°C], with subsequent quenching in water or rapidly cooling by other means.

6.2.3 As a final heat treatment, the ferritic/austenitic grade UNS S32760, shall be reheated in the temperature range of 2010° to 2085°F [1100° to 1140°C] for an appropriate time, with subsequent quenching in water or rapidly cooling by other means.

A99 **6.2.4** As a final heat treatment, the ferritic/austenitic grade UNS S39274, shall be reheated to a temperature of 1920° to 2060°F [1025° to 1125°C] with subsequent quenching in water or rapidly cooling by other means. UNS S32550 shall be annealed at 1950° to 1975°F [1065° to 1080°C], and water quenched.

6.3 *Martensitic* — As a final heat treatment, the Martensitic Grade UNS S41500 shall be reheated to a temperature of 1750°F [955°C] minimum and air cooled to 200°F [95°C] or lower prior to any optional intermediate temper and prior to final temper. The final temper shall be between 1050°F and 1150°F [565°C and 625°C]. WP410 shall be heat treated in accordance with 6.1.

6.4 All welding shall be done prior to final heat treatment.

6.5 Fittings machined directly from a forging or bar stock that has been annealed need not be reannealed.

7. Chemical Composition

7.1 The chemical composition of each cast or heat shall be determined and shall conform to the requirements of the chemical composition for the respective grades of materials listed in Table 1. Methods and practices relating to chemical analyses required by this specification shall be in accordance with Methods, Practices, and Definitions A 751. Product analysis tolerances in accordance with Table 2 are applicable.

7.2 Except as listed below, in fittings of welded construction, the composition of the deposited weld shall conform to the same requirements as the base metal. A99

7.2.1 Welds on S23950 base metal shall be made with nominal 26% Cr, 8% Ni 2% Mo weld metal. A99

7.2.2 Welds on S31803 base metal shall conform to the same requirements as the base metal or shall be made with nominal 22% Cr, 8 to 10% Ni, 3% Mo weld metal. A99

8. Tensile Requirements

8.1 The tensile properties of the fitting material shall conform to the requirements of Table 3. The testing and reporting shall be performed in accordance with Test Methods and Definitions A 370.

8.2 At least one tension test per heat shall be made on material representative of the fitting, including weld metal when filler metal is added, and in the same condition of heat treatment as the finished fitting it represents.

8.3 The fittings manufacturer shall perform a tensile test on material representative of the finished fitting. Records of the tensile test made on the starting material may be certification that the material of hot-finished fittings meets the tensile requirements of this specification provided the heat treatments are the same.

9. Hardness Requirements

9.1 Fittings shall not exceed the maximum hardness shown in Table 3.

10. Dimensions

10.1 The sizes, shapes, and dimensions of the fittings covered by ANSI B16.9, ANSI B16.11, ANSI B16.28, MSS SP-43 or MSS SP-79, shall be as specified in those standards.

10.2 Fittings of size or shape differing from these standards, but meeting all other requirements of this specification, may be furnished in accordance with Supplementary Requirement S8.

11. Workmanship, Finish, and Appearance

11.1 Fittings supplied under this specification shall be examined visually. Selected typical surface discontinuities shall be explored for depth. The fittings shall be free from surface discontinuities that penetrate more than 5% of the specified nominal wall thickness, except as defined in 11.3 and 11.4, and shall have a workmanlike finish.

11.2 Surface discontinuities deeper than 5% of the specified nominal wall thickness, except as defined in 11.3 and 11.4, shall be removed by the manufacturer by machining or grinding to sound metal, and the repaired areas shall be well faired. The wall thickness at all points shall be at least 87½% of the specified nominal wall thickness, and the diameters at all points shall be within the specified limits.

11.3 Surface checks (fish scale) deeper than $\frac{1}{64}$ in. [0.4 mm] shall be removed.

11.4 Mechanical marks deeper than $\frac{1}{16}$ in. [1.6 mm] shall be removed.

11.5 When the removal of a surface discontinuity reduces the wall thickness below 87½% of the specified nominal wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in 11.6.

11.6 *Repair by Welding:*

11.6.1 Repair welding, of the base metal by the manufacturer, is permissible for fittings made to the dimensional standards listed in 1.1 or for other standard fittings made for stock. Prior approval of the purchaser is required to repair special fittings made to the purchaser's requirements. Repair by welding shall neither exceed 10% of the outside surface area of the fitting nor 33⅓% of the nominal wall thickness.

11.6.2 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

11.6.3 The alloy content (carbon, chromium, nickel, molybdenum, columbium, and titanium) of the deposited weld metal shall be within the same percentage range as permitted for the base metal.

NOTE 1 — **Caution**: When selecting the filler metal and welding procedure, consideration should be given to their effect on corrosion resistance in service.

11.6.4 Surface discontinuities deeper than 5% of the specified nominal wall thickness shall be removed by mechanical means or thermal cutting or gouging methods. Cavities prepared for welding shall be examined by the liquid penetrant method of Practice E 165. No cracks shall be permitted in the prepared cavities. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

11.6.5 The weld repair shall be permanently identified with the welder's stamp or symbol in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code.

11.6.6 Weld repair area(s) shall be blended uniformly to the base metal and shall be examined by liquid penetrant in accordance with Practice 165. No cracks shall be permitted in the weld or surrounding ½ in. [13 mm] of base metal. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

11.6.7 After weld repair, material shall be heat treated in accordance with Section 6.

11.7 The fittings shall be cleaned free of scale.

12. Hydrostatic Tests

12.1 Hydrostatic testing is not required by this specification.

12.2 Each fitting of Class WP shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure equal to that prescribed for the specified matching pipe or equivalent material.

12.3 Each fitting of Class CR, except tees covered in 12.3.1, shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure based on the ratings in MSS SP-43.

12.3.1 Class CR tees fabricated using intersection welds shall be capable of passing a hydrostatic test based on 70% of the ratings in MSS SP-43.

13. Inspection

13.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy the inspector that all material is being furnished in accordance with this specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All examinations and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

13.2 Other tests, when agreed upon, shall be made from material of the lots covered in the order.

14. Rejection

14.1 Unless otherwise specified, any rejection based on tests by the purchaser shall be reported to the manufacturer within 30 working days from the receipt of samples or test reports by the purchaser.

14.2 Each fitting that develops surface discontinuities deeper than 5% of the specified nominal wall thickness in shop working or application operations may be rejected and the manufacturer so notified.

15. Rehearing

15.1 Test samples that represent fittings rejected by the purchaser shall be preserved for four weeks from the date of the rejection report. In case of dissatisfaction with the test results, the manufacturer may make claim for a rehearing within the period that the samples are preserved.

16. Certification

16.1 When requested by the purchaser, the manufacturer shall provide a certificate of conformance to this specification (including year date). In addition, if requested to provide test reports, the manufacturer shall also provide the following where applicable:

16.1.1 Chemical results, Section 7 (Table 1),

16.1.2 Tensile results, Section 8 (Table 2). Report yield strength and ultimate tensile strength in ksi [MPa], and elongation in percent,

16.1.3 Type of heat treatment, Section 6,

16.1.4 Starting material; plate, bar, pipe (specify welded or seamless), forging,

16.1.5 Seamless or welded construction,

16.1.6 Any supplemental testing required by the purchase order, and

16.1.7 Heat identification.

17. Product Marking

17.1 All fittings shall have the prescribed information stamped or otherwise suitably marked on each fitting in accordance with the latest edition of Standard Marking System for Valves, Fittings, Flanges and Unions (MSS SP-25).

17.2 Marking paint or ink shall not contain harmful metal or metal salt, such as zinc, lead, or copper, which cause corrosive attack on heating. On wall thicknesses thinner than 0.083 in. [2 mm], no metal impression stamps shall be used. Vibrating pencil marking is acceptable.

17.3 The prescribed information for butt-welding fittings shall be: the manufacturer's name or trademark (Note 2), schedule number or nominal wall thickness designation, size, class, specification number (year date not needed), grade (Table 1) and the heat number or manufacturer's heat identification.

NOTE 2 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component complies with this specification.

17.4 The prescribed information for threaded or socket-welding fittings shall be: the manufacturer's name or trademark, (Note 2) pressure class or schedule number or wall thickness designation, size, class, specification number (year date not needed), grades (Table 1) and the heat number or manufacturer's heat identification.

17.5 *Bar Coding* — In addition to the requirements in 17.1, 17.2, 17.3, and 17.4, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 corrosive service applications; ferritic/austenitic stainless steel; ferritic stainless steel; marstensitic stainless steel; pipe fittings-steel; piping applications; pressure containing parts; stainless steel fittings

TABLE 1
CHEMICAL REQUIREMENTS

Note — Where an ellipsis (. . .) appears in this table, there is no requirement.

	Composition, %											
Grade	C, max	Mn, max	P, max	S, max	Si, max	Ni	Cr	Mo	Cu, max	N	Ti	Other
						Ferritic Steels						
WP27	0.010	0.75	0.020	0.020	0.40	0.50 max	25.0–27.50	0.75–1.50	0.20	0.015 max	. . .	Cb 0.05–0.20
WP33	0.06	0.75	0.040	0.020	0.75	0.50 max	25.0–27.0	0.75–1.50	0.20	0.040 max	0.20–1.00 (7 × (C + N)) min	. . .
WP429	0.12	1.0	0.040	0.030	0.75	0.50 max	14.0–16.0	. . .	. . .	. . .	. . .	. . .
WP430	0.12	1.00	0.040	0.030	1.00	0.50 max	16.0–18.0	. . .	. . .	. . .	. . .	. . .
WP430Ti	0.10	1.00	0.040	0.030	1.00	0.75 max	16.0–19.50	. . .	. . .	. . .	(5 × C) min 0.75 max	. . .
WP446	0.20	1.50	0.040	0.030	0.75	0.50 max	23.0–30.0	. . .	. . .	0.10–0.25	. . .	. . .
						Ferritic/Austenitic Steels						
UNS S31803	0.030	2.0	0.030	0.020	1.0	4.50–6.50	21.0–23.0	2.50–3.50	. . .	0.08–0.20	. . .	. . .
S32750	0.030	1.2	0.035	0.020	0.8	6.0–8.0	24.0–26.0	3.0–5.0	0.5	0.24–0.32	. . .	. . .
S32950	0.03	2.00	0.035	0.010	0.60	3.50–5.20	26.00–29.00	1.00–2.50	. . .	0.15–0.35	. . .	. . .
S32760	0.030	1.00	0.030	0.010	1.00	6.00–8.00	24.0–26.0 [Note (1)]	3.00–4.00 [Note (1)]	0.50–1.00	0.20–0.30 [Note (1)]	. . .	. . .
S39274	0.030	1.0	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.50–3.50 [Note (1)]	0.20–0.80	0.24–0.32	. . .	W 1.50–2.50
S32550	0.04	1.5	0.040	0.030	1.00	4.5–6.5	24.0–27.0	2.9–3.9	1.5–2.5	0.10–0.25	. . .	. . .
						Martensitic Steels						
WP410	0.15	1.00	0.040	0.030	1.00	0.50 max	11.5–13.5	. . .	. . .	. . .	. . .	. . .
UNS S41500	0.05	0.5–1.0	0.030	0.030	0.60	3.5–5.5	11.5–14.0	0.5–1.0	. . .	. . .	. . .	W 0.50–1.00

NOTE:
(1) % Cr + 3.3 × % Mo + 16 × % N = 40 min.

TABLE 2
PRODUCT ANALYSIS TOLERANCES FOR HIGHER ALLOY AND STAINLESS STEELS [NOTE (1)]

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	0.030, incl	0.005
	over 0.030 to 0.20 incl	0.01
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
	over 3.00 to 6.00	0.05
	over 6.00 to 10.00	0.06
Phosphorus	to 0.040, incl	0.005
Sulfur	to 0.030, incl	0.005
Silicon	to 1.00, incl	0.05
	over 1.00 to 1.40, incl	0.10
Chromium	over 4.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
	over 15.00 to 20.00, incl	0.20
	20.00 to 27.50, incl	0.25
Nickel	to 1.00, incl	0.30
	over 1.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
	over 20.00 to 22.00, incl	0.20
Molybdenum	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
	over 2.00 to 7.00, incl	0.10
Titanium	all ranges	0.05
Copper	to 0.50	0.03
Nitrogen	to 0.19 incl	0.01
	over 0.19 to 0.25	0.02
	over 0.25 to 0.35	0.03
	over 0.35 to 0.45	0.04
Columbium	0.05 to 0.20, incl	0.01
Tungsten	to 1.00	0.04

NOTE:
(1) This table does not apply to heat analysis.

A99

TABLE 3
TENSILE AND HARDNESS REQUIREMENTS

Grade	Yield Strength, ksi [MPa]	Tensile Strength, ksi [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Brinell Hardness BHN max
Ferritic Steels:				
WP27	40 [275]	65 [450]–90 [620]	20.0	190
WP33	45 [310]	68 [470]–93 [640]	20.0	241
WP429	35 [240]	60 [415]–85 [585]	20.0	190
WP430	35 [240]	65 [450]–90 [620]	20.0	190
WP430Ti	35 [240]	60 [415]–85 [585]	20.0	190
WP446	40 [275]	70 [485]–95 [655]	18.0	207
Ferritic/Austenitic Steels:				
UNS				
S31803	65 [450]	90 [620]	25.0	290
S32750	80 [550]	116 [800]–140 [965]	15.0	310
S32760	80 [550]	109 [750]–130 [895]	25.0	270
S32950	70 [485]	100 [690]	15.0	290
S39274	80 [550]	116 [800]	15.0	310
S32550	80 [550]	110 [760]	15.0	302
Martensitic Steels:				
WP410	30 [205]	70 [485]–95 [655]	20.0	207
UNS				
S41500	90 [620]	110 [760]–135 [930]	15.0	295

SUPPLEMENTARY REQUIREMENTS FOR WELDING FITTINGS REQUIRING SPECIAL CONSIDERATION

One or more of the supplementary requirements described below may be included in the purchaser's inquiry or in the order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier.

S1. Product Analysis (Note 3)

S1.1 A product analysis shall be made for each heat of base metal and, if of welded construction, from each lot number of welding material of the fittings offered for delivery and shall conform to the requirements specified in Section 8.

NOTE 3 — If the results of any of the tests specified in Supplementary Requirements S1, S2 or S3 do not conform to requirements, retests may be made at the manufacturer's expense on additional fittings or representative test pieces of double the original number from the same heat or lot as defined in Supplementary Requirements S1, S2, or S3, each of which shall conform to the requirements specified.

S2. Tension Test (Note 3)

S2.1 One tension test shall be made on one fitting or representative test piece (Note 4) per lot (Note 5) of fittings. If the fittings are of welded construction, the tension specimen shall include the weld and be prepared so that the weld is at the midlength of the specimen.

NOTE 4 — Where the test specimen for the tension or intergranular corrosion bend test cannot be taken from a fitting due to size limitations, a representative test piece shall be obtained. The test piece shall be from the same lot it represents and shall have approximately the same amount of working. In addition, these pieces representing fittings manufactured from bars, plate or forgings shall have a cross section equal to the greatest cross section of the fitting, and test pieces representing fittings manufactured from tubular products shall have a cross section approximately the same as that of the finished product. The test piece for fittings of welded construction shall be prepared to the same weld procedures and from the same heats of materials as the fittings it represents.

NOTE 5 — A lot shall consist of all fittings of the same type, size, and wall thickness, manufactured from one heat of material (and, if fabrication welding is performed using one lot number of electrode or one heat of weld wire), and heat treated using the same heat treat cycle in either a continuous or batch-type furnace controlled within a range of 50°F [28°C] and equipped with recording pyrometers so that complete records of heat treatment are available.

S3. Intergranular Corrosion Bend Test (Note 3)

S3.1 An intergranular corrosion bend test shall be made on one fitting or representative test piece (Note 4) per lot (Note 5) of fittings. If the fittings are of welded construction, the bend specimen shall include the weld and be prepared so that the weld is at the midlength location of the specimen. Specimens containing a weld shall be bent so that the location of weld is at the point of maximum bend. The method of testing shall be in accordance with Practices A 262 or Practices A 763, as applicable.

S4. Ultrasonic Test

S4.1 Each fitting or the raw material from which each fitting is made shall be ultrasonically tested to determine its soundness. The method, where applicable, shall be in accordance with Practice A 388. Acceptance limits shall be specified by the purchaser. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

S5. Photomicrographs

S5.1 Photomicrographs at 100 diameters shall be made for information only of the actual base metal structure from one fitting as furnished in each lot. The photomicrographs shall be identified as to fitting size, wall thickness, lot identification, and heat. The definition of "lot" shall be as specified by the purchaser.

S6. Surface Finish

S6.1 Machined surfaces shall have a maximum roughness of 250 RMS (root-mean-square) or 6.3 μin. AA (arithmetical average). All other surfaces shall be suitable for ultrasonic testing.

S7. Liquid Penetrant Test

S7.1 All surfaces shall be liquid penetrant tested. The method shall be in accordance with Practice E

165. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

S8. Special Fittings

S8.1 Partial compliance fittings of size and shape not conforming to the dimensional requirements of ANSI B16.9, B16.11, B16.28, or MSS SP-79 shall meet all other requirements of this specification. In addition to the marking required in Section 18, the grade designation symbol shall be followed by the symbol "S8."

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, CHROMIUM-MOLYBDENUM-VANADIUM

SA-832/SA-832M

(Identical with ASTM Specification A 832/A 832M-95 except for editorial difference in Table 1.)

1. Scope

1.1 This specification covers chromium-molybdenum-vanadium alloy steel plates intended primarily for the fabrication of welded pressure vessels.

1.2 The plates furnished under this specification are required to be normalized-and-tempered. Specification A 542/A 542M includes coverage of the material in the quenched-and-tempered condition.

1.3 The maximum thickness of plates furnished to this specification is limited only by the capacity of the composition to meet the specified property requirements. However, the maximum thickness of plates normally furnished under this specification is 6 in. [150 mm].

1.4 The material is intended to be suitable for fusion welding. Welding technique is of fundamental importance and it is presupposed that welding procedures will be in accordance with approved methods.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system, must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 542/A 542M Specification for Pressure Vessel Plates, Alloy Steel, Quenched-and-Tempered, Chromium-Molybdenum-Vanadium, and Chromium-Molybdenum-Vanadium-Titanium-Boron

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M establishes the rules for ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examina-

tion is required to meet end use requirements. These include the following:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M. If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Process* — The steel shall be made by one of the processes permitted in Specification A 20/A 20M.

4.2 *Steelmaking Practice* — The steel shall be killed.

5. Heat Treatment

5.1 All plates shall be normalized and tempered. The minimum normalizing temperature for Grade 22V shall be 1650°F [900°C]. The minimum normalizing temperature for Grade 23V shall be 1850°F [1010°C]. The minimum tempering temperature shall be 1250°F [675°C].

5.2 Plates ordered without the heat treatment required by 5.1 shall be furnished in either the stress-relieved or the annealed condition. Heat treatment of plates so ordered, to conform to 5.1 and to Table 2, shall be the responsibility of the purchaser.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition shown in Table 1.

7. Mechanical Properties

7.1 *Tension Test Requirements:*

7.1.1 The material as represented by the tension test specimens shall conform to the requirements of Table 2.

7.2 *Notch Toughness Requirements:*

7.2.1 A transverse Charpy V-notch test from each plate as heat-treated shall have a minimum energy absorption value of 40 ft · lbf [54 J] average of three specimens and 35 ft · lbf [48 J] for one specimen only in the set.

7.2.2 The notch toughness test temperature shall be 0°F [−18°C].

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %		
	Grade 21V	Grade 22V	Grade 23V
Carbon			
Heat analysis	0.10–0.15	0.11–0.15	0.10–0.15
Product analysis	0.08–0.18	0.09–0.18	0.08–0.18
Manganese			
Heat analysis	0.30–0.60	0.30–0.60	0.30–0.60
Product analysis	0.25–0.66	0.25–0.66	0.25–0.66
Phosphorus, max	0.025[A]	. . .	0.025
Heat analysis	. . .	0.015	
Product analysis	. . .	0.020	
Sulfur, max	0.025[A]	. . .	0.010
Heat analysis	. . .	0.010	
Product analysis	. . .	0.015	
Silicon, max			
Heat analysis	0.10	0.10	0.10
Product analysis	0.13	0.13	0.13
Chromium			
Heat analysis	2.75–3.25	2.00–2.50	2.75–3.25
Product analysis	2.63–3.37	1.88–2.62	2.63–3.37
Molybdenum			
Heat analysis	0.90–1.10	0.90–1.10	0.90–1.10
Product analysis	0.85–1.15	0.85–1.15	0.85–1.15
Vanadium			
Heat analysis	0.20–0.30	0.25–0.35	0.20–0.30
Product analysis	0.18–0.33	0.23–0.37	0.18–0.33
Titanium			
Heat analysis	0.015–0.035	0.030, max	
Product analysis	0.005–0.045	0.035, max	
Boron			
Heat analysis	0.001–0.003	0.0020, max	
Product analysis	NA[B]	NA[B]	
Copper, max			
Heat analysis	. . .	0.20	
Product analysis	. . .	0.23	
Nickel, max			
Heat analysis	. . .	0.25	
Product analysis	. . .	0.28	
Columbium, max			
Heat analysis	. . .	0.07	0.015–0.070
Product analysis	. . .	0.08	0.010–0.075
Calcium, max[C]			
Heat analysis	. . .	0.015	0.0005–0.0150
Product analysis	. . .	0.020	NA[B]

[A] Applies to both heat analysis and product analysis.
[B] NA = Not Applicable.
[C] Rare earth metals (REM) may be added in place of calcium, subject to agreement between the producer and the purchaser. In that case, the total amount of REM shall be determined and reported.

TABLE 2
TENSILE REQUIREMENTS

Tensile strength, ksi, [MPa]	85–110 [585–760]
Yield strength, min, ksi, [MPa]	60 [415]
Elongation in 2 in. [50 mm], min, % [Note (3)]	18
Reduction of area, min, %	45 [Note (1)]
	40 [Note (2)]

NOTES:
(1) Measured on round specimen.
(2) Measured on flat specimen.
(3) See Specification A 20/A 20M for elongation adjustments.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A 20/A 20M. Some of those considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4. Additional Tension Test,

S6. Drop-Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S14. Bend Test,

S19. Restricted Chemical Requirements.

SPECIFICATION FOR COMMON REQUIREMENTS FOR IRON CASTINGS FOR GENERAL INDUSTRIAL USE

SA-834

(Identical with ASTM Specification A 834-94.) 98

1. Scope

1.1 This specification covers a group of requirements that are mandatory requirements when used in conjunction with the following iron casting specifications issued by ASTM:

ASTM Specification
A 47
A 48
A 197
A 220
A 278
A 319
A 395
A 436
A 439
A 536
A 571

1.2 This specification also covers a group of supplementary requirements which may be applied to the above specifications as indicated herein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 The requirements of the individual material specification, and this general specification shall prevail in the sequence named.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:* 98

A 47 Specification for Ferritic Malleable Iron Castings
A 48 Specification for Gray Iron Castings
A 197 Specification for Cupola Malleable Iron
A 220 Specification for Pearlitic Malleable Iron Castings
A 247 Test Method for Evaluating the Microstructure of Graphite in Iron Castings
A 278 Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F
A 319 Specification for Gray Iron Castings for Elevated Temperatures for Non-Pressure Containing Parts
A 395 Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures
A 436 Specification for Austenitic Gray Iron Castings
A 439 Specification for Austenitic Ductile Iron Castings
A 536 Specification for Ductile Iron Castings
A 571 Specification for Austenitic Ductile Iron Castings for Pressure-Containing Parts Suitable for Low-Temperature Service
A 644 Terminology Relating to Iron Castings
A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination
A 919 Terminology Relating to Heat Treatment of Metals
E 8 Test Methods of Tension Testing of Metallic Materials
E 10 Test Method for Brinell Hardness of Metallic Materials
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron

E 59 Test Method for Sampling Steel and Iron for Determination of Chemical Composition
E 94 Guide for Radiographic Testing
E 165 Practice for Liquid Penetrant Examination
E 351 Test Methods for Chemical Analysis of Cast Iron — All Types
E 689 Reference Radiographs for Ductile Iron Castings
E 709 Practice for Magnetic Particle Examination
E 802 Reference Radiographs for Gray Iron Castings Up to 4½ in. (114 mm) in Thickness

2.2 *Military Standard:*
MIL-STD-129 Marking for Shipment and Storage

2.3 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

3. Terminology

3.1 *Definitions:*

98 **3.1.1** Definitions for many terms common to iron castings and their heat treatment may be found in Terminology A 919 and Terminology A 644. A classification of graphite structure is found in Test Method A 247.

4. Ordering Information

4.1 The purchase order for castings ordered under this specification shall stipulate the applicable material specification(s), grade of iron, and any options or additions to the basic requirements, including the supplementary requirements included in this specification.

5. Chemical Requirements

5.1 The individual product specifications vary as to whether chemical analysis is required. To determine specific requirements, the individual product specification should be reviewed.

5.2 Sampling shall be conducted in accordance with Test Method E 59. Spectrographic or other methods such as those in Test Methods E 30 and E 351 may be used for chemical analysis. In the event of a dispute regarding chemical composition, Test Methods E 351 and E 30 shall be used for referee purposes.

5.3 The chemical analysis for total carbon shall be made on chilled pencil-type specimens or from thin wafers approximately 1/32 in. (0.8 mm) thick cut from test coupons. Drillings are not reliable because of a probable loss of graphite.

5.4 Chemical analysis results shall be rounded, in accordance with Practice E 29, to the nearest unit in the last right-hand place of values in the table of chemical requirements.

5.5 A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis shall be taken no closer than ¼ in. to a cast surface, and shall follow the practice in 5.3, except where the size or shape of the casting does not permit such sampling. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved.

6. Tensile Requirements

6.1 The individual product specifications vary as to whether tension tests are required. For this reason, and to determine specific test requirements, the individual product specification should be reviewed. When required, tension tests shall be determined in accordance with Test Methods E 8.

7. Workmanship, Finish, and Appearance

7.1 All castings shall be made in a workman-like manner and shall conform to the dimensions on drawings furnished by the purchaser before manufacture is started. If the pattern is supplied by the purchaser, the dimensions of the casting shall be as predicted by the pattern.

8. Sampling

8.1 A lot shall consist of one of the following:

8.1.1 All the metal from a single heating in a batch-type melting furnace.

8.1.2 All the metal poured from two or more 98
batch-type melting furnaces into a single ladle or a single casting.

8.1.3 All the metal poured from a continuous melting furnace for a given period of time between changes in charge, processing conditions, or aim-for chemistry, or 4 h, whichever is the shorter period.

8.1.3.1 The purchaser may agree to extend the 4-h time period to 8 h if the manufacturer can demonstrate sufficient process control to warrant such an extension.

9. Inspection

9.1 All tests and inspections required by this specification shall be performed by the manufacturer or other reliable sources whose services have been contracted for by the manufacturer. Complete records of all tests and inspections shall be maintained by the manufacturer and shall be available for review by the purchaser.

9.2 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations.

9.3 When agreed upon between manufacturer and purchaser, test specimens or unbroken test bars from the same lot shall be saved for a period of 3 months after date of the test report.

9.4 When unbroken test bars are reprocessed with castings for rehearing, test specimens from these bars shall be saved, as described in 9.3.

9.5 The purchaser reserves the right to perform any inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to the prescribed requirements.

10. Repair

10.1 Any repair shall be made in accordance with the requirements of the individual specification using procedures qualified by the manufacturer for the type of repair involved.

11. Rejection and Rehearing

11.1 Castings which fail to conform to the requirements specified when inspected or tested by the purchaser or his agent may be rejected. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the test results, the manufacturer or supplier may make claim for a rehearing.

12. Packaging and Package Markting

12.1 Unless otherwise specified in the contract or purchase order, cleaning, preservation, and packaging of castings shall be in accordance with the manufacturer's commercial practice. Packing and marking shall also be adequate to identify the contents and to ensure acceptance and safe delivery by the carrier for the mode of transportation employed.

12.2 *Government Procurement* — When specified in the contract or purchase order, marking for shipment shall be in accordance with the requirements of Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military activities.

13. Quality Assurance

13.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Visual Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

13.2 When additional inspection is desired, Supplementary Requirements S1, S2, or S3, may be specified.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Magnetic Particle Examination

S1.1 Castings shall be examined for surface discontinuities by magnetic particle examination. The examination shall be in accordance with Practice E 709. The extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S2. Radiographic Examination

S2.1 Castings shall be examined for internal defects by means of X-rays or gamma rays. The procedure shall be in accordance with Guide E 94, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 689 and E 802. The extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S3. Liquid Penetrant Examination

S3.1 Castings shall be examined for surface discontinuities by means of liquid penetrant examination. The examination shall be in accordance with Practice E 165. Areas to be inspected, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S4. Certification

S4.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification, including the year date, and was found to meet the requirements. Additionally, the certification shall include for each lot the results of all tests required by the material specification and any supplementary or additional requirements imposed by the purchase order.

S4.2 A signature is not required on the certification or test report. However, the document shall clearly identify the organization submitting the certification and the authorized agent of the manufacturer who certified the test results. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

S4.3 The test report shall be furnished within 5 working days of shipment of the castings.

S5. Prior Approval of Major Repairs

S5.1 Major repairs as defined and agreed upon between the manufacturer and purchaser shall be subject to the prior approval of the purchaser.

S6. Marking

S6.1 The manufacturer's name or identification mark and the part identification number shall be cast or stamped on all castings. When further specified, lot numbers shall be marked on individual castings.

S6.2 When the castings are of such size that individual marking is impracticable, they shall be grouped by part identification or lot number and placed in a container. The container shall be marked with the required identification.

S7. Hardness Test

S7.1 Hardness measurements at specified locations on the castings shall be made in accordance with Test Method E 10 and reported.

SPECIFICATION FOR FORGINGS, TITANIUM-STABILIZED CARBON STEEL, FOR GLASS-LINED PIPING AND PRESSURE VESSEL SERVICE

SA-836/SA-836M

(Identical with ASTM Specification A 836/A 836M-95b.) 98

1. Scope

1.1 This specification covers nonstandard as-forged fittings, valve components, and parts for glass-lined piping and pressure vessel service. Mechanical properties are certified on the basis of test material subjected to heat treatments to simulate glass-coating operations.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

98 2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 788 Specification for Steel Forgings, General Requirements

E 165 Practice for Liquid Penetrant Inspection Method

E 709 Practice for Magnetic Particle Examination

2.2 *ASME Boiler and Pressure Vessel Code:*

Section IX Welding Qualifications

2.3 *Military Standard:*

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

3. Ordering Information 98

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

3.1.1 Quantity,

3.1.2 Dimensions (Tolerance and surface finishes should be included),

3.1.3 Specification number and class (The year date should be included),

3.1.4 Supplementary requirements, and

3.1.5 Additional requirements (see 10.1, 13.1, 13.2, 13.3, and 15.2).

4. Materials and Manufacture

4.1 Material for forgings shall consist of ingots, or forged, rolled, or strand cast blooms, billets, slabs, or bars.

4.2 The material shall be forged by hammering, pressing, rolling, extruding, or upsetting, such that the

finished product will be a forging as defined in the Terminology Section of Specification A 788.

4.3 A sufficient discard shall be made from the source material to secure freedom from injurious piping and undue segregation.

4.4 When specified in the order, the manufacturer shall submit for approval by the purchaser a sketch showing the shape of the rough forging before machining.

4.5 Forgings shall be protected against sudden or too rapid cooling from the rolling or forging while passing through the critical range.

4.6 Heat treatment of forgings is neither required nor prohibited. However, the test material for qualifying the forging or the welding procedure shall be heat treated to simulate glass-coating operations.

5. Chemical Composition

5.1 *Cast or Heat Analysis*—An analysis of each cast or heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The analysis shall be made from a test sample, preferably taken during the pouring of the cast or heat. The chemical composition thus determined shall conform to the requirements in Table 1.

5.2 *Product Analysis:*

5.2.1 The purchaser may make a product analysis on forgings supplied to this specification by any of the commonly accepted methods that will positively identify the material. Samples for analysis may be taken from midway between center and surface of solid forgings, midway between inner and outer surfaces of hollow forgings, midway between center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 1 within the permissible variations of Table 2.

5.2.2 Test Methods, Practices, and Terminology A 751 apply.

6. Mechanical Properties

6.1 The test material shall conform to the requirements as to tensile properties prescribed in Table 3.

6.2 Testing shall be performed in accordance with Test Methods and Definitions A 370.

7. Test Specimens

7.1 The test material to be used for qualifying the forgings shall be heat treated with the forgings represented by the test material, if the forgings are heat treated, then, the test material shall be normalized three times from a minimum temperature of 1550°F [845°C] prior to testing. This heat treatment simulates glass-coating operations.

7.2 The tension test specimens shall be machined to the form and dimensions of the standard 2 in. [50 mm] gage length tension test specimen shown in Fig. 4 of Test Methods and Definitions A 370, except as specified in 7.3.

7.3 In the case of small sections that will not permit taking standard test specimens as specified in 7.2, the tension test specimen shall be as large as feasible and its dimensions shall be proportional to those shown in Fig. 4 of Test Methods and Definitions A 370. The gage length for measuring elongation shall be four times the diameter of the specimen.

7.4 For the purpose of determining conformance to Table 3, specimens shall be obtained from the production forgings, or from separately forged test blanks prepared from the stock used to make the finished product. Such test blanks shall receive approximately the same working as the finished product.

8. Workmanship, Finish, and Appearance

8.1 The forgings shall be free of injurious imperfections as defined below and shall have a workmanlike finish. At the discretion of the inspector representing the purchaser, finished forgings shall be subject to rejection if surface imperfections acceptable under 8.3 are not scattered but appear over a large area in excess of what is considered a workmanlike finish.

8.2 *Depth of Injurious Imperfections*—Selected typical linear and other typical surface imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness of the finished forging, such imperfections shall be considered injurious.

8.3 *Machining or Grinding Imperfections Not Classified as Injurious*—Surface imperfections not classified as injurious shall be treated as follows:

8.3.1 Forgings showing seams, laps, tears, or slivers not deeper than 5% of the nominal wall thickness or $\frac{1}{16}$ in. [2 mm], whichever is less, need not have these imperfections removed. If the imperfections require

removal, they shall be removed by machining or grinding.

8.3.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed the limitations set forth in 8.2 and if not deeper than $\frac{1}{16}$ in. [2 mm]. If such imperfections are deeper than $\frac{1}{16}$ in. but do not encroach on the minimum wall thickness of the forging they shall be removed by grinding to sound metal.

8.3.3 When imperfections have been removed by grinding or machining, the outside dimension at the point of grinding or machining may be reduced by the amount removed. When impracticable to secure a direct measurement, the wall thickness at the point of grinding, or at imperfections not required to be removed, shall be determined by deducting the amount removed by grinding, from the nominal finished wall thickness of the forging; the remainder shall not be less than the minimum specified or required wall thickness.

9. Number of Tests and Retests

9.1 One tension test shall be made from each heat.

9.2 If any test specimen is defectively machined, it may be discarded and another specimen substituted.

9.3 When one or more representative test specimens do not conform to specification requirements for the tested characteristic, only a single retest for each nonconforming characteristic may be performed to establish product acceptability. Retests shall be performed on twice the number of representative specimens that were originally nonconforming. When any retest specimen does not conform to specification requirements for the characteristic in question, the lot represented by that specimen shall be rejected, or the test material shall be reheat-treated in accordance with 4.6 and 7.1, and tested in accordance with Sections 6, 7, and 9.

10. Repair by Welding

10.1 Approval by the purchaser shall be required prior to weld repair.

10.2 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. The welded test plate used to qualify the procedure shall be normalized three times at 1550°F [845°C] prior to testing to simulate glass-coating operations.

10.3 The composition of the weld deposits shall be similar to the base metal and in accordance with the procedure qualification for the applicable material. Welding shall be accomplished with a weld procedure designed to produce low hydrogen in the weldment. Short-circuit gas metal arc welding is permissible only with the approval of the purchaser.

10.4 Unacceptable imperfections shall be removed by mechanical means or thermal cutting or gouging methods. Cavities prepared for welding shall be examined by one of the following methods to verify removal of the imperfection:

10.4.1 Magnetic particle examination in accordance with Test Method A 275/A 275M or Practice E 709, or

10.4.2 Liquid penetrant examination in accordance with Practice E 165.

10.5 Weld repaired area(s) shall be blended uniformly to the base metal and shall be examined by the method used in 10.4.

10.6 Repair by welding shall neither exceed 10% of the surface area of the part, nor $33\frac{1}{3}$% of the wall thickness of the finished product at the location of repair, without prior approval by the purchaser.

11. Inspection

11.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

12. Rejection and Rehearing

12.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

12.2 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon by the manufacturer and the purchaser.

13. Certification

13.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. The specification designation included on test reports shall include year of issue and revision letter, if any.

13.2 When specified in the purchase order or contract, a report of the test results shall be furnished.

13.3 Upon request of the purchaser in the contract or order, a report of the test results and chemical analyses shall be furnished.

14. Marking of Forgings

14.1 Identification marks consisting of the manufacturer's symbol or name (Note), designation of service rating, this specification number, class, and size shall be legibly forged or stamped on each forging, and in such a position as not to injure the usefulness of the forgings. The specification number marked on the forgings need not include specification year of issue and revision letter.

NOTE—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

14.2 *Bar Coding* — In addition to the requirements in 14.1, bar coding is acceptable as a supplementary identification method. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag. 98

15. Packaging, Marking, and Loading for Shipment

15.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

15.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, when level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

16. Keywords 98

16.1 pipe fittings, steel; piping applications; pressure containing parts; pressure vessel service; steel flanges; steel forgings-carbon; steel valves

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %
Carbon, max	0.20
Manganese, max	0.90
Phosphorus, max	0.05
Silicon, max	0.35
Sulfur, max	0.05
Titanium, min	4 × carbon content
Titanium, max	1.00

TABLE 2
PERMISSIBLE VARIATIONS IN PRODUCT ANALYSIS

	Permissible Variations Over the Maximum Limit or Under the Minimum Limit, %[A,B]				
	200 in.^{2} [1290 cm^2] and Under	Over 200 to 400 in.^{2} [1290 to 2580 cm^2], incl	Over 400 to 800 in.^{2} [2580 to 5160 cm^2], incl	Over 800 to 1600 in.^{2} [5160 to 10 320 cm^2]	Over 1600 in.^{2} [10 320 cm^2]
Manganese					
Up to and including 0.90	0.04	0.05	0.06	0.07	0.08
Phosphorus	0.008	0.010	0.010	0.015	0.015
Sulfur	0.010	0.010	0.010	0.015	0.015
Silicon	0.03	0.04	0.04	0.05	0.06

[A] Product cross-sectional area is defind as (*a*) maximum cross-sectional area of rough machined forging (excluding boring), (*b*) maximum cross-sectional area of the unmachined forging, or (*c*) maximum cross-sectional area of the billet, bloom or slab.

[B] Area taken at right angles to the axis of the original ingot or billet.

TABLE 3
TENSILE REQUIREMENTS

	Class I
Tensile strength, min, ksi [MPa]	55 [380]
Yield strength,[A] min, ksi [MPa]	25 [175]
Elongation in 2 in. or 50 mm, min, %	22
Reduction of area, min, %	35

[A] Determined by either 0.2% offset method or the 0.5% extension-under-load method.

SPECIFICATION FOR STEEL PLATES FOR PRESSURE VESSELS, PRODUCED BY THE THERMO-MECHANICAL CONTROL PROCESS (TMCP)

SA-841/SA-841M

(Identical with ASTM Specification A 841/A 841M-90.) 98

1. Scope

1.1 This specification covers steel plates produced by the thermo-mechanical control process (TMCP). The plates are intended primarily for use in welded pressure vessels.

1.2 The TMCP method consists of rolling-reduction and cooling rate controls which result in mechanical properties in the finished plate that are equivalent to those attained using conventional rolling and heat treating processes which entail reheating after rolling. A description of the TMCP method is given in Appendix X1.

1.3 Due to the inherent characteristics of the TMCP method, the plates cannot be formed at elevated temperatures without sustaining significant losses in strength and toughness. The plates may be formed and post-weld heat-treated at temperatures not exceeding 1200°F [650°C], providing the requirements of 6.1 are met.

1.4 The maximum nominal thickness of plates furnished under this specification may not exceed 4 in. [100 mm].

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents. Therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for ordering information which should be complied with when purchasing material to this specification.

3.2.1 When the material is to be subjected to warm forming or post-weld heat treatment, the order must indicate the temperatures and times-at-temperature that will be utilized in such operations. (See 6.1 and Specification A 20/A 20M, Supplementary Requirement S3.)

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are

available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Additional or special impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A 20/A 20M.

4.2 The plates shall be produced by the thermo-mechanical control process.

5. Chemical Composition

5.1 The chemical composition on heat analysis shall conform to the requirements listed in Table 1, except as otherwise provided in Supplementary Requirement S17 of Specification A 20/A 20M when that requirement is involved.

5.2 If a product analysis is made on a sample taken from the standard location (see Specification A 20/A 20M), the results of the analysis shall not deviate from the limits for the heat analysis by more than the values given in Table 2.

6. Mechanical Requirements

6.1 When the material is to be subjected to warm forming or post-weld heat treatment, the test coupons shall be subjected to heat treatment to simulate such fabrication operations. (See 3.2.1 and Specification A 20/A 20M, Supplementary Requirement S3.)

6.2 *Tension Test Requirements*—The plates as represented by the tension-test specimens shall conform to the requirements shown in Table 3.

6.2.1 *Number and Location of Test Coupons*—Two tension tests shall be made from each plate-as-rolled. One test coupon shall be taken from a corner of the plate on each end.

6.3 *Notch Toughness Test Requirements:*

6.3.1 Longitudinal Charpy V-notch tests shall be made in accordance with Specification A 20/A 20M.

6.3.2 The test results of full-size specimens shall meet an average value of 15 ft·lbf [20 J] at −40°F [−40°C].

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %
Carbon, max	0.20
Manganese	
$t \leqq$ 1.5 in. [40 mm]	0.70–1.35 [A]
$t >$ 1.5 in. [40 mm]	1.00–1.60
Phosphorus, max	0.030
Sulfur, max	0.030
Silicon	0.15–0.50
Copper, max	0.35
Nickel, max	0.25
Chromium, max	0.25
Molybdenum, max	0.08
Columbium, max	0.03
Vanadium, max	0.06
Aluminum, min	0.020 total or 0.015 acid soluble

[A] Manganese may exceed 1.35% on heat analysis, up to a maximum of 1.60%, provided that the carbon equivalent on heat analysis does not exceed 0.47%, or the value specified in Supplementary Requirement S77 when that requirement is invoked, when based on the following formula.

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15\%$$

When this option is exercised, the manganese content on product analysis shall not exceed the heat analysis content by more than 0.12.%

TABLE 2
PRODUCT ANALYSIS TOLERANCES

		Tolerances, %	
Element	Specified Limit	Under, Minimum	Over, Maximum
Carbon	to 0.15, incl	0.02	0.03
	over 0.15	0.03	0.04
Manganese	to 0.60, incl	0.05	0.06
	over 0.60 to 0.90, incl	0.06	0.08
	over 0.90 to 1.20, incl	0.08	0.10
	over 1.20 to 1.35, incl	0.09	0.11
	over 1.35 to 1.65, incl	0.09	0.12
Phosphorus	to 0.020, incl	. . .	0.005
	over 0.20	. . .	0.010
Sulfur	to 0.020, incl	. . .	0.005
	over 0.020	. . .	0.010
Silicon	to 0.30, incl	0.02	0.03
	over 0.30 to 0.40, incl	0.05	0.05
	over 0.40	0.06	0.06
Nickel	to 1.00, incl	. . .	0.03
Chromium	to 0.90, incl	. . .	0.04
Molybdenum	to 0.20, incl	. . .	0.01
Copper	to 1.00, incl	. . .	0.03
Vanadium	to 0.10, incl	. . .	0.01
Columbium	to 0.10, incl	. . .	0.01
Aluminum	to 0.15, incl	0.005	0.01

TABLE 3
TENSILE REQUIREMENTS

Thickness	Yield Strength, min ksi [MPa]	Tensile Strength, ksi [MPa]	Elongation in 2 in., min, %	Elongation in 8 in., min, %[A]
to 2.5 in.	50	70–90	22	18
[to 65 mm]	345	[485–620]	22	18
over 2.5 in.	45	65–85	22	18
[over 65 mm]	310	[450–585]	22	18

[A] See Specification A 20/A 20M for elongation adjustments.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A 20/A 20M. Several of those that are considered for use with this specification are listed in this section by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test,

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A 435/A 435M,

S9. Magnetic Particle Examination,

S10. Charpy V-Notch Test Curve,

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M,

S13. NDT Temperature Determination,

S14. Bend Test (pin diameter subject to agreement),

S17. Vacuum Carbon-Deoxidized Steel,

S18. Unspecified Elements, and

S19. Restricted Chemical Requirements.

ADDITIONAL SUPPLEMENTARY REQUIREMENT

Also listed is an additional supplementary requirement suitable for use with this specification.

S77. Carbon Equivalent Limit

S77.1 The carbon equivalent, on heat analysis, shall not exceed the limits listed in this section when based on the following equation:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Cu + Ni)/15\%$$

$t =$ 2 in. [50 mm] and under in thickness	0.40%
$t =$ 2 in. [50 mm] in thickness	0.45%

APPENDIX

(Nonmandatory Information)

X1. THERMO-MECHANICAL CONTROL PROCESS (TMCP)

X1.1 *Introduction*—The Thermo-Mechanical Control Process, commonly referred to as "TMCP," has evolved from the "controlled rolling" processes which have been known and used for a number of years. TMCP is the new generation of controlled rolling. TMCP produces fine-grained steel by a combination of chemical composition and integrated controls of manufacturing processes from slab reheating to post-rolling cooling, thereby achieving the specified mechanical properties in the required plate thicknesses. TMCP requires accurate control of both steel temperature and rolling reductions.

X1.2 *Outline of TMCP*—As shown in Fig. X1.1, TMCP may incorporate two processes, as follows:

X1.2.1 *Thermo-Mechanical Rolling (TMR)*—Steels of fine grain size are produced by rolling in the recrystallization and the nonrecrystallization regions of austenite, and some-times in the dual-phase temperature region of austenite and ferrite. Generally, a high proportion of the rolling reduction is performed close to, or below, the temperature at which austenite begins to transform to ferrite during cooling (Ar3) and may involve rolling in the lower portion of the temperature range of the intercritical duplex phase region.

X1.2.2 *Accelerated Cooling (AC)*—Steels meeting the specified requirements are produced by promoting grain refinement and increasing the pearlite or bainite, or both, volume fraction through controlled cooling (accelerated cooling and air cooling) in the dual-phase temperature region immediately after the final controlled rolling (CR) or TMR operation.

X1.3 The selection, from the above, of the method to be used is made by the plate producer depending upon the chemical composition, the plate thickness, and the required properties.

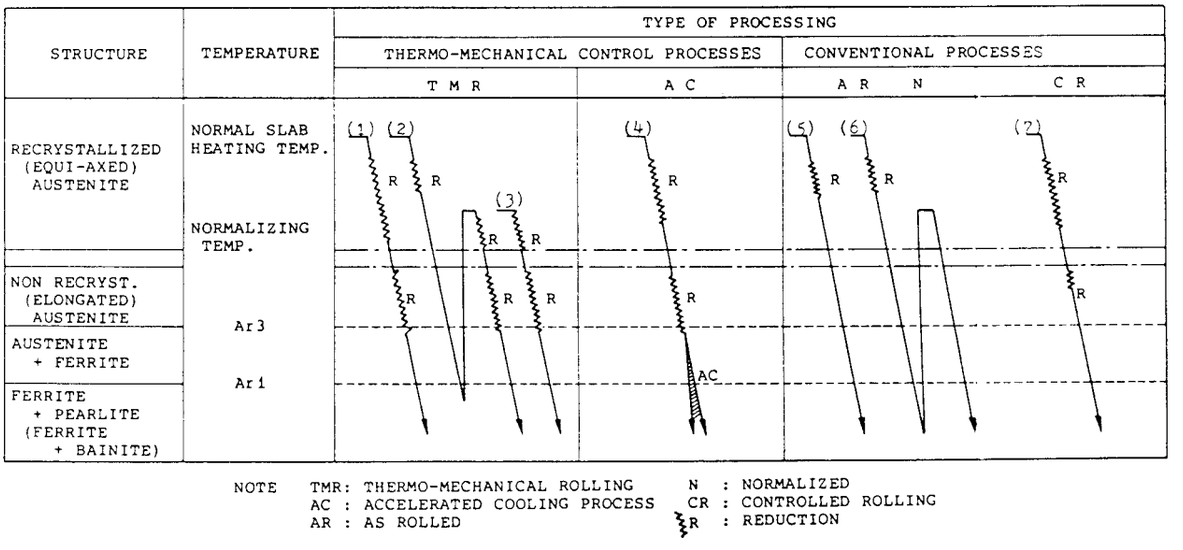


FIG. X1.1 SCHEMATIC DIAGRAMS OF THERMO-MECHANICAL CONTROL AND CONVENTIONAL PROCESS OF STEEL PLATE

SPECIFICATION FOR STEEL WIRE, PRESSURE VESSEL WINDING

SA-905

(Identical with ASTM Specification A 905-93.) 98

1. Scope

1.1 This specification covers requirements for a high strength drawn and cold rolled steel wire in two strength classes, with rectangular cross section, and round mill edge. This wire is intended for prestressed vessel and press frame windings.

1.2 The values stated in either inch-pound units or SI (metric) units are to be regarded separately as standards. Within the text and tables, the SI units are shown in parentheses. The values stated in each system are not exact equivalents. Therefore, each system must be used independent of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 510 Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel

A 510M Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel [Metric]

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

E 30 Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron and Wrought Iron

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

2.2 *Military Standard:*

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.4 *AIAG Standard:* 98

AIAG B-502.00 Primary Metals Identification Tag Application Standard

3. Ordering Information

3.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 510 or A 510M.

3.2 Orders for material under this specification shall include the following information for each ordered item.

3.2.1 Quantity (mass),

3.2.2 Name of material,

3.2.3 Dimensions (see Section 7),

3.2.4 Finish (see Section 8),

3.2.5 Packaging (see Section 11),

3.2.6 Heat analysis report (see 5.2),

3.2.7 Number of certification and test reports required,

3.2.8 ASTM designation and year of issue, and

3.2.9 Supplementary requirements, if any.

4. Material and Manufacture

4.1 The steel shall be produced by any of the following primary processes: (1) basic oxygen, and (2) electric furnace or vacuum induction (VIM). The pri-

mary melting may incorporate separate degassing or refining and may be followed by secondary melting by the electrode slag process (ESR) or the vacuum arc remelting process (VAR).

4.1.1 The steel may be ingot cast or continuously cast.

4.2 The finished wire shall be free from detrimental pipe and undue segregation.

4.3 The wire shall be cold drawn or cold rolled, or both, to produce the desired mechanical properties and dimensions after subjecting it to the patenting treatment.

4.4 The width to thickness ratio of the wire cross section shall not exceed 8.

5. Chemical Composition

5.1 The steel shall conform to the requirements for chemical composition prescribed in Table 1.

5.2 *Heat Analysis*—Each heat of steel shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 1. This analysis shall be made from a test specimen preferably taken during the pouring of the heat. When requested, this shall be reported to the purchaser and shall conform to the requirements of Table 1.

5.3 *Heat Number Assignment for Sequentially Strand Cast Material*—When heats of the same chemical composition are sequentially strand cast, the heat number assigned to the cast product may remain unchanged until all of the steel in the product is from the following heat.

5.4 *Product Analysis*—An analysis may be made by the purchaser from finished wire representing each heat of steel. The chemical composition thus determined, as to elements required or restricted, shall conform to the product analysis requirements specified in Table 10 of Specification A 510 or A 510M.

5.5 For referee purposes, Methods E 30 shall be used.

6. Mechanical Requirements

6.1 *Tension Test:*

6.1.1 *Requirements*—The material as represented by tension test specimens shall conform to the requirements prescribed in Table 2.

6.1.2 *Number of Tests*—One test specimen shall be taken from each end of every coil.

6.1.3 *Test Method*—The tension test shall be made in accordance with Test Methods A 370, except that the length L for evaluation of the elongation shall be calculated from the following formula:

$$L = 11.3\sqrt{W \cdot T}$$

where:

W = width of the wire, and
T = thickness of the wire.

The length L shall be used to calculate the permanent elongation. The distance between the gage marks shall be measured to the nearest 0.004 in. (0.1 mm). Determine tensile properties and permanent elongation as described in Test Methods A 370.

6.1.4 *Retest*—If any test specimen exhibits obvious discontinuity, it may be discarded and another specimen substituted.

7. Dimensions and Permissible Variations

7.1 The permissible variations in dimensions of the wire shall be as specified in Table 3, unless otherwise specified in the ordering information.

8. Workmanship, Finish, and Appearance

8.1 The wire shall be free of detrimental surface imperfections, tangles and sharp kinks.

8.2 The wire shall conform to the dimensions, tolerances, and finish specified on the order or drawing. Welds are not permitted.

8.3 When required, non-destructive examination shall be carried out in accordance with Supplementary Requirement S1.

8.4 The wire as received shall be smooth and substantially free from rust. No detrimental die marks or scratches may be present.

9. Inspection

9.1 All tests and inspections shall be made at the place of manufacture unless otherwise agreed upon, and shall not interfere unnecessarily with the manufacturer's operations. The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification.

10. Certification and Reports

10.1 The manufacturer shall furnish the required number, from the purchase order, of test reports to the purchaser. The following items shall be reported.

10.1.1 Heat number,

10.1.2 Heat chemical analysis,

10.1.3 Result of test of tensile properties,

10.1.4 Reports of non-destructive tests, if required (S.1), and

10.1.5 ASTM specification number, year of issue and revision letter, if any.

11. Packaging, Marking, and Loading for Shipment

11.1 The coil, reel or spool mass, dimensions, and the method of packaging shall be agreed upon between the manufacturer and purchaser.

11.2 The size of the wire, purchaser's order number, ASTM specification number, and name or mark of the manufacturer shall be marked on a tag securely attached to each coil, reel, or spool of wire.

11.3 Unless otherwise specified in the purchaser's order, packaging, marking, and loading for shipments shall be in accordance with those procedures recommended by Practices A 700.

11.4 *For Government Procurement*—Packaging, packing, and marking of material for military procurement shall be in accordance with the requirements of MIL-STD-163, Level A, Level C, or commercial as specified in the contract or purchase order. Marking for shipment of material for civil agencies shall be in accordance with Fed. Std. No. 123.

11.5 *Bar Coding* — In addition to the previously-stated identification requirements, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard 02.00, Primary Metals Identification Tag Application. The bar code may be applied to a substantially affixed tag. **98**

12. Keywords **98**

12.1 pressure vessel; winding; wire

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition %
Carbon	0.80–0.95
Manganese	0.30–0.60
Phosphorus	0.025
Sulphur, max	0.020
Silicon	0.10–0.30

TABLE 2
TENSILE REQUIREMENTS

Thickness[A] in. (mm)	Tensile Strength min, ksi (MPa)		Yield Strength min, ksi (MPa)		Elongation min, %	
	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2
0.020 (051)	296 (2045)	268 (1850)	260 (1795)	232 (1600)	4.0	5.0
0.030 (0.76)	290 (2000)	262 (1810)	255 (1760)	226 (1560)	4.0	5.0
0.040 (1.02)	285 (1965)	256 (1770)	250 (1725)	221 (1525)	4.0	5.0
0.051 (1.30)	280 (1930)	250 (1725)	243 (1680)	214 (1480)	4.0	5.0
0.059 (1.50)	275 (1900)	246 (1700)	239 (1650)	210 (1450)	4.0	5.0

[A] Tensile requirement values for intermediate thickness may be interpolated.

TABLE 3
PERMISSIBLE VARIATIONS IN DIMENSIONS

Thickness in. (mm)	Permissible Variation, ± in. (mm)
0.02 to 0.03 (0.51 to 0.76), incl	0.0004 (0.01)
Over 0.03 to 0.04 (0.76 to 1.02), incl	0.0008 (0.02)
Over 0.04 to 0.06 (1.02 to 1.52), incl	0.0012 (0.03)
Width in. (mm)	**Permissible Variation, ± in. (mm)**
0.08 to 0.16 (2.03 to 4.06), incl	0.0016 (0.04)
Over 0.16 to 0.24 (4.06 to 6.10), incl	0.0024 (0.06)
Over 0.24 to 0.48 (6.10 to 12.2), incl	0.0040 (0.10)

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements to this specification shall only apply to a product specification when specified by the purchaser in his inquiry, contract or order. Details of the supplementary requirements shall be agreed upon in writing between the manufacturer and purchaser.

S1. Surface Examination

S1.1 The surface of the wire shall be examined by the eddy current method in accordance with Practice E 309. The acceptance criteria shall be mutually agreed upon by the purchaser and manufacturer.

SPECIFICATION FOR STRUCTURAL QUALITY STEELS

SA/CSA-G40.21

(Identical with CAN/CSA-G40.21-92, with the additional requirements listed on this cover sheet. No other Edition is approved for ASME use.) 98

1. Additional Requirements

1.1 Marking:
In addition to the marking requirements of this specification, all products are to be identified by this SA/CSA specification designation.

2. Source

2.1 CSA-G40.21-92 can be obtained from:
Canadian Standards Association
178 Rexdale Boulevard
Etobicoke, Ontario
Canada M9W 1R3
Phone: (416) 747-4000
Fax: (416) 747-4149

SPECIFICATION FOR FLAT PRODUCTS MADE OF STEELS FOR PRESSURE PURPOSES

SA/EN 10028-2

(Identical with BS EN 10028-2-1993 with the additional requirements listed on this cover sheet. No other Edition is approved for ASME use.) 98

1. Additional Requirements

1.1 Marking

In addition to the marking requirements of this specification, all products are to be identified by this SA/EN specification designation.

Material that has been given the full heat treatment required by para. 8.2.1 or 8.2.2 shall be marked with the letters "MT", following the marked specification designation, by the party performing the heat treatment.

Plates that are not heat treated but that are qualified on the basis of heat treated specimens per para. 8.2.3 shall be stamped with the letter "G" following the stamped specification designation.

2. Mechanical Properties

The mechanical properties required in Table 3 for product thickness over 150 mm shall be the same as those for 100–150 mm.

3. Source

3.1 BS EN 10028-2, and its references, can be obtained from:

BSI — British Standards Institution
389 Chiswick High Road
London W4 4AL
Phone: 0181 996 9000
Fax: 0181 996 7500

SPECIFICATION FOR CARBON STEEL PLATES FOR PRESSURE VESSELS FOR INTERMEDIATE AND MODERATE TEMPERATURE SERVICE

A99

SA/JIS G3118

(Identical with JIS G3118-1987, as translated and published in the English language by the Japanese Standards Association with the additional requirements listed on this cover sheet. No other Edition is approved for ASME use.)

1. Additional Requirements

1.1 Marking:

In addition to the marking requirements of this specification in para. 11, all products are to be identified by this SA/JIS specification designation.

2. Mechanical Properties

2.1 Tension testing is mandatory. Metric symbol materials (Table 1-2) shall use the values in Table 3-2 only.

3. Repair Welding

3.1 Weld repairs may be performed when permitted by the purchaser. The requirements of SA-20 shall apply.

4. Source

4.1 JIS G3118 and its references can be obtained from:

Japanese Standards Association
1-24, Akasaka 4, Minato-ku
Tokyo 107 Japan